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UNITED STATES
DEPARTMENT OF THE INTERIOR

DRAFT
ENVIRONMENTAL STATEMENT

VOLUME 1 OF 2

PROPOSED
INCREASE IN ACREAGE TO BE OFFERED
FOR OIL AND GAS LEASING
ON THE OUTER CONTINENTAL SHELF

DES 74-90

Prepared by the
BUREAU OF LAND MANAGEMENT

Curt Berklund
Director

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Summary

(X) Draft ( ) Final Environmental Statement
Department of the Interior, Bureau of Land Management
Division of Minerals Environmental Assessment

1. Proposed Increase in Outer Continental Shelf Oil and Gas Leasing to Ten Million Acres in 1975

(X) Administrative ( ) Legislative Action

2. It is proposed to increase the acreage offered for OCS oil and gas exploration and development so that ten million acres are leased in 1975. This proposal, if implemented, would entail leasing in frontier areas which have little or no history of such development. The possible environmental impacts of such an increase are examined, and several scenarios are presented by which this proposal could be effected.

3. Alternatives considered:

A. Alternative Sale Scheduling to Increase Leasing

B. Increase OCS Leasing in Modified Form

C. No Increase in OCS Leasing

D. Postpone Increase in OCS Leasing

E. Discontinue OCS Leasing

F. Energy Alternatives

G. Alternative OCS Exploratory Programs

H. Alternative Lease Bidding Systems

I. Alternative Management and Supervisory Systems

J. Alternative Technology Options

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4. Comments have been requested from the following:

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Federal Power Commission

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State of North Carolina
State of South Carolina
State of Georgia
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State of Alabama
State of Louisiana
State of Texas
State of California
State of Oregon
State of Washington
State of Alaska

6. Draft statement made available to Council on Environmental Quality and the public on October 18, 1974.

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Attachment G Maps of 17 OCS Areas

Attachment H Report on Responses Received in Reply to the Request for Comments on Potential Future OCS Oil and Gas Leasing

Attachment I Tentative Designations for Lease Sales in 1975

Note:

This draft environmental statement has been prepared pursuant to section 102(2)(c) of the National Environmental Policy Act of 1969.

The regulations to which reference is made throughout this environmental statement are 30 CFR Part 250 and 43 CFR 3300, and Geological Survey OCS Orders Nos. 1 through 12 - Gulf of Mexico, and OCS Orders Nos. 1 through 10 - Pacific. The OCS Orders for the Gulf of Mexico and Pacific have been appended to this statement. Although too bulky to append in entitirety, pertinent portions of the relevant CFR's are appended. The entire CFR's may be obtained from the United States Department of the Interior.

I. DESCRIPTION OF PROPOSED ACTION

A. Statement of Proposed Action

1. Purpose of Proposed Action

The proposed action which is the subject of this draft environmental impact statement is the expansion of Outer Continental Shelf (OCS) oil and gas leasing to the point where ten million acres are leased in 1975 on the United States OCS. As a result of this proposed increase into higher potential areas, the prospects of finding new hydrocarbon energy sources will be significantly enhanced. As domestic prospects are enhanced, production of oil and gas will eventually be higher, and reliance of the U.S. on imported energy sources will decrease by approximately the amount of the domestic production increase. The amount of acreage that must be offered in order to lease ten million acres will be significantly higher than that figure, perhaps up to twenty million acres. The actual amount to be offered can not be determined at this time, as it is dependent on such factors as geographic area, hydrocarbon potential of different areas, availability of materials necessary for development, environmental safeguards in selection of areas and supervision of operations, and an assurance of fair market value return to the Federal Government for the lands being leased.

//

On January 23, 1974, President Nixon addressed the Nation on proposals intended to deal with energy crises. He outlined an extensive legislative and regulatory program which he urged Congress and Executive agencies to act upon in 1974. Included were measures to deal with the short-term emergency of that period, as well as measures designed to achieve long-term self-sufficiency for the United States in energy supply (Project Independence). Among these legislative proposals were:

establishment of a Federal Energy Administration (implemented)

mandatory reporting of information by private industry (in planning)

market pricing of new natural gas (under review)

Federal licensing of offshore deepwater port facilities (under review)

elimination of depletion allowance for foreign oil and gas production (under review)

modernization of the Mineral Leasing Act (under review)

facilitation of the site selection, approval, and licensing process for energy facilities (under review)

In addition to the legislative program, the President announced a number of executive actions designed to aid in achieving energy self-sufficiency for the United States. One of these, which is the subject of this draft environmental impact statement, relates directly to outer continental shelf (OCS) oil and gas exploration and development:

> "I am directing the Secretary of the Interior to increase the acreage leased on the OCS to 10 million acres beginning in 1975, more than tripling what had originally been planned. In later years, the amount of acreage to be leased will be based on market needs and on industry's performance record in exploring and developing leases. In contracting for leases, the Secretary of the Interior is also to ensure that the proper competitive bidding procedures are followed and that environmental safeguards are observed. He will, in addition, set up an interagency program for monitoring the environmental aspects of the new leasing program. There will be no decision on leasing on the OCS in the Atlantic and in the Gulf of Alaska until the Council on Environmental Quality completes its current environmental study of those areas."

Pursuant to this directive, the Department of the Interior announced in May 20, 1974 Federal Register that an environmental impact statement will be prepared concerning the proposed action of leasing ten million acres of OCS lands in 1975. This announcement was made because the proposal is considered a major Federal action significantly affecting the quality of the human environment, and therefore requires an environmental impact statement under the requirements of the National Environmental Policy Act of 1969. The Federal Register notice announced in part, that

> "It is the intention of the Bureau of Land Management to prepare an environmental statement which, in general, will describe the following topics: The proposed leasing action; the management system pertaining to the proposed action, including leasing procedures, supervision, inspection, and regulation of lease operations and monitoring

> of actual and threatened environmental effects of lease operations; OCS oil and gas resource potential; energy supply and demand; technology for developing oil and gas offshore; environmental settings; natural phenomena that exist or occur in particular OCS regions, and which have the potential to cause or contribute to environmental impacts arising from the proposed action; the potential environmental impacts of the proposed action, offshore and onshore, including without limitation matters such as the cumulative impact of oil and gas operations under the proposed leasing action, impacts on competing uses of OCS resources, the effect of the proposed action of the level of environmental study prior to leasing and on the level of supervision of lease operations after leasing, and the degree to which environmental effects might be reduced as a result of improvements in methods of lease supervision; and the alternatives to the proposed action and their potential environmental impacts."

Non-dependence, or significant curtailment of dependence on foreign energy imports is one of the primary goals of Project Independence, which also contains proposals to research and develop alternate energy sources, to establish a climate of reduced energy demands through conservation practices, and to reduce energy losses through more efficient generation and transmittal of energy sources. As President Nixon's message indicated, this proposed increase in offshore leasing will not be undertaken until the Secretary of the Interior ensures that proper competitive bidding procedures are followed to assure a fair market return to the Federal Government on the production from the leases, and that proper environmental safeguards are observed.

The remainder of this draft environmental impact examines the aspects of the proposed action announced in the Federal Register Notice referred to earlier. Discussions immediately follow on the scope of the proposed action and the underlying assumptions concerning both the proposed action and this draft environmental impact statement.

2. Scope of the Proposed Action

The Presidential directive to lease 10 million acres in 1975 represents more than tripling of the acreage currently offered annually for lease by private industry. The directive represents a significant change in Federal Government policy concerning the development of domestic OCS oil and gas resources. As stated in the preceding section, the purpose of this proposal is to significantly expand the Nation's domestic oil and gas energy supply, as long as this can be done in an environmentally safe manner and in a manner that insures fair market return to the Federal Government for allowing these lands to be developed as sources of energy.

The scope of this proposed action is wide-reaching because of one salient point. Currently, the Nation's entire supply of domestic OCS oil and gas comes from the Gulf of Mexico, specifically the Texas-Louisiana OCS. If a commitment is made to this proposed (or some other) level of expansion of acreage offered for leasing, it would necessarily have to commit new areas to leasing and development that have no history of OCS leasing. Several indicators (BLM-GS estimates of tract worth, industry bidding patterns, OCS production summaries) show the central Gulf area to be one of declining potential for economically recoverable oil and gas reserves. The eastern Gulf of Mexico is estimated to have only limited potential. A proposed three million acre sale in the

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western Gulf is estimated to produce about as much oil and gas as recent 1 million acre sales in the central Gulf have been estimated to produce. There are approximately 6,300,000 acres currently under Federal lease for oil and gas development in the Gulf of Mexico. If the indications of declining prospects in the Gulf are accepted as valid, then a significant expansion of acreage offered would not, if offered in the Gulf alone, result in increased production of OCS oil and gas resources for our domestic needs. Therefore, this expansion to 10 million acres of leased OCS land in 1975 must include geographic areas of the United States that have experienced little or no history of offshore oil and gas operations. These frontier areas include the Atlantic coast, lower 48 Pacific coast, and the coast of Alaska. The Atlantic and Alaska OCS areas have no history of drilling activity; Alaska has State coastal water development in Cook Inlet, but the Atlantic waters belonging to the coastal states do not currently produce any oil or gas. There has been some development of the coastal ad OCS waters of Southern California; however, drilling on Federal lands has been suspended since the Santa Barbara blowout and oil spill in early 1969.

The opening of frontier areas to OCS oil and gas leasing is a proposal that, if implemented, will result in significant changes in physical, social, and economic environments, as well as an expansion of management, supervisory, and monitoring systems within Federal and States' governments. Certain elements of the current OCS leasing program will carry over and be applied to an expanded program. Development in any frontier area will not begin until Operating Orders, similar to those used in the Gulf of Mexico, are developed for the specific geographic area. Current regulations and inspection programs will be applied to frontier development. Under the current three million acre per year schedule, frontier areas were scheduled to be opened in Southern California and Alaska. In response to this, the Bureau of Land Management, in August and September, 1973, respectively, opened field offices in these two areas with responsibilities for collecting physical and socio-economic information, conducting environmental analysis on proposed development in the respective areas, and performing all the functions attendant to leasing lands in those areas. An Atlantic OCS Office was also established in December of 1973 with the purpose of environmental assessment of the area, but without a leasing function, as leasing on the Atlantic coast was contingent on the Council of Environmental Quality's assessment of the impact of oil and gas development in the area (released April, 1974), and is contingent on the resolution of current litigation against development brought by several coastal states against the Federal Government.

The aforementioned lease sale schedule is a proposed five-year schedule of provisional leasing that was developed in July, 1973. In the development of the schedule, the Department considered its three leasing objectives; orderly resource development, protection of the environment, and receipt of fair market value. These objectives constitute overall policy parameters for the OCS program. An analysis was made at that time of when, where, and how much oil and gas acreage to offer for lease. This was done through a review of the national energy situation and the identification of future supply-demand imbalances. Deficits were identified by matching projections of future non-OCS supplies of oil and gas and future OCS production from existing leases with future projected demand. Demand forecasts were made on a regional basis, using the regions of the Future Requirements Committee for gas and the Petroleum Administration for Defense districts for oil. The schedule is shown in Figure 1. The schedule indicates a sale for the Mississippi, Alabama, and Florida (MAFLA) sale in 1973. This area is a frontier area with no history of OCS oil and gas operations. Opposition to that proposal was extremely vocal, especially from the public and institutional sectors of Florida. This opposition elicited a major commitment from the Department of the Interior to begin a comprehensive environmental baseline and monitoring study of the effects of OCS oil and gas operations in this area. The initial contract for the baseline data collection (which has been completed) was awarded to the State University System of Florida Institute of Oceanography (SUSIO). During the development of the MAFLA study program, the Department, with a multi-million dollar commitment from the Office of Management and Budget, expanded the plans for environmental baseline and monitoring studies to include other frontier OCS areas of the United States. Study plans are currently being developed for the South Texas, Gulf of Alaska, and Southern California areas. These study programs are discussed in more detail in another section of this statement.

Subsequent to President Nixon's directive to lease 10 million acres in 1975, the Bureau of Land Management issued a request for comments on potential future OCS oil and gas leasing (Federal Register, February 20, 1974). These comments were to be directed toward providing information concerning areas of interest for offshore oil and gas leasing and toward identifying problem areas. Seventeen areas were designated which encompass the OCS of the coterminous United States and Alaska. It was requested that these areas be ranked for oil and gas potential, and for environmental concern. The report on the responses received has been completed and is included as Attachment

This request for information is the first tier of the Department's newly developed two-tier nomination system, whereby the most promising offshore areas are better identified through earlier release of industry rankings and interest, and the public interest in different geographic areas is also made known earlier in the leasing process. The second tier of the system involves analysis of rankings and public comments, the Department's own evaluation of resource potential and the impacts of development on the environment, and the nomination and selection of tracts within specified geographic areas for possible leasing. This is followed by the currently employed phases of the leasing system: a site-specific draft environmental impact statement, public hearings in the affected area, Federal and State agencies and public review of the impact statement, and the development of a final environmental impact statement in which all the various inputs are summarized and from which conditions and stipulations of the lease sale are formulated. The leasing process is more fully discussed in a later section.

In addition to the aforementioned first tier of the nomination system, the BLM and USGS are exploring various options whose intent would be to require earlier release of geological and geophysical information in areas designated for lease sales. This information would be especially valuable in areas of non-production, as producing areas do not require as much geotechnical information to evaluate current prospects. The proposals for early information release are complicated by the historically proprietary nature of such information, bearing as it does on the competitive nature of lease acquisition and tract development. Various options are discussed in this document.

Various leasing methods have also been proposed and are being reviewed. Under current legislation, the Secretary of the Interior has the discretion of offering leases in only two ways: fixed royalty with bonus bidding, or royalty bidding with fixed bonus or rental fees. Most OCS leasing has been done in the bonus bidding mode, although an imminent sale (Louisiana #36) includes 10 tracts being offered on a royalty bidding basis. These tracts are being offered on an experimental basis, to allow the Department to analyze such a system. The bonus bidding system, with its requirement of front-end capital, has been attacked as favoring large companies which can generate such capital. Other systems, all of which require legislative approval, are discussed later as alternative leasing programs which may be developed and applied to the 10 million acre program.

The BLM, as well as other management and policy offices of the Interior Department, has been able to keep pace somewhat in its staffing needs in minerals management. Field offices in our four major OCS regions (Atlantic, Gulf of Mexico, Pacific, and Alaska) have been established and are either adequately staffed or are in the process of becoming so. The USGS, on the other hand, has the bulk of the supervisory responsibilities for OCS operations. As such, it must adjust its staffing needs in accordance with the current and near-term needs of the supervisory program. Supervision of operations that would take place on an expanded scale (both spatially and in intensity) under the 10 million acre leasing proposal must be significantly expanded. Information from the USGS indicates that it has requested funding for fiscal 1975 for increased staff and inspections, mostly in response to the possibility of an expanded leasing program. Another major responsibility of the USGS, the promulgation and revision of OCS Operating Orders, may also be aided by the increased staff request.

These aspects, and others, of the current leasing program and the proposed expanded program are addressed elsewhere in this impact statement. However, those aspects of management, supervision, and implementation of the program, while necessary, are not the most important aspects of this expanded program. What is most important is how the proposal relates to the quality of human life in the United States. Quality of life (as it is affected by this program) can only be determined by a multi-level analysis of the consequences of the program. At the national level, most people are benefitted, in some way, by increased availability of domestically derived energy. At the local level, benefits accrue from development through jobs and services, but negative impacts can be sustained because of oil spills, boom-bust development, and chronic stresses on the physical, biological, and social environments. These impacts must be adequately portrayed.

3. Underlying Assumptions

There are numerous assumptions that must be made when a program, such as leasing ten million acres of OCS lands, is being developed. Many of the assumptions relate to the environmental impact statement that is required under the National Environmental Policy Act of 1969 for all significant Federal actions affecting the human environment. This draft impact statement on the proposed action includes assumptions that relate to its intent and purpose.

This impact statement differs from previous impact statements concerning OCS oil and gas operations in that it addresses a particular policy (the extent and location of possible leasing) rather than a specific proposal (a lease sale). The policy being addressed, however, will result in specific proposals of the type recently experienced in the Gulf of Mexico. In this sense, the impact statement on the proposed action must examine in broad terms the possible specific proposals that may follow the proposed policy action. The specific proposals that may result from this proposed action were discussed under I. 2., namely, leasing OCS lands in frontier areas. Therefore, this draft impact statement will describe, in general terms, conditions on, above, and landward of the U. S. outer continental shelf, as well as the general impacts of leasing and developing the hydrocarbon resources contained therein. While no leasing was anticipated in 1975 on the

Atlantic coast when this document was being formulated, the Department felt that the discussion should include this area for completeness and for planning purposes beyond 1975. The recent decision of the Special Master of the Supreme Court denying Atlantic states claims to OCS land makes the decision to include the Atlantic coast in this document more justifiable, although the Supreme Court has not made its final ruling and no leasing plans have been initiated.

Although the impact statement includes discussions on all U. S. OCS lands and the impacts of oil and gas development thereon, it does so from a generalized approach. This was done for several reasons. First, this impact statement, either the draft or the final, will not substitute for a site-specific impact statement in any area for any given leasing proposal. Site-specific impact statements for any given leasing proposal will be developed in the normal procedure of tract nomination and selection, draft impact statement, public hearings and public, institutional, Federal, and State review and comment on the statement, and a final environmental impact statement. Secondly, a full and complete description of OCS lands and waters, and of the coastal states adjacent to them, would be a monumental task producing a bulky, unmanageable, and probably unreadable document. Most of the material found in this statement is considerably condensed from a variety of sources. The references in the Literature Cited section concluding the document should be consulted for more complete discussions of most topics.

One other reason for the generalized approach derives from the fact that many OCS areas are of a frontier nature regarding OCS hydrocarbon development. While these areas can be described in physical, biotic and socio-economic terms, the impacts and stresses of development will be wholly new. Much of the information used for elucidating impacts is derived from Gulf of Mexico experience which, while it offers many insights and some conclusions regarding impacts, does not always lend itself to the unique characteristics of other regions. Also, since Louisiana and Texas (State and Federal) waters have undergone development for many years with concomitant land-based development and dependence, these may no longer be suitable areas from which to project the initial, short-term impacts for the frontier areas, impacts that may be the most stressful.

Many of the impacts can be generalized for all the OCS regions. For example, the impact of spilled oil on phytoplankton is generally the same wherever it occurs, regardless of the species composition of the phytoplankton assemblage. What are more important are the levels of primary productivity in different areas; reductions of these levels have more significance to ecosystem vitality than a description of species most affected. Other topics in the impact section will be discussed for the OCS regions as a whole; impacts on specific regions will be discussed where the uniqueness of the area necessitates a separate treatment.

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The assumptions made above all point to and determine the intent of this impact statement. Since the statement addresses 1) a proposed policy program which, if implemented, will result in more specific proposals, 2) broad geographical areas in general terms, and 3) many of the impacts of OCS leasing in general terms, the impact statement is more of a planning document than previous site-specific OCS oil and gas impact statements have been. Several scenarios are presented for leasing 10 million acres. A tentative lease sale listing is appended as Attachment I.

The final impact statement, along with further resource analysis, contributions from public hearings, economic, political, and national security considerations, and responses to actual or potential litigation, will be used to determine the feasibility of the expanded program, the scheduling of sales in all geographic (including frontier) areas, and the magnitude of the individual sales.

B. Proposed Oil and Gas Resource Management and Supervision System

Proposed OCS Leasing Procedures (Administered by BLM)

a. Proposed Lease Sale Scheduling

A schedule for 1975 is in the process of being constructed; it is this schedule that deals with the 10 million acre leasing effort for CY 75. An effort is also being made to construct a schedule for a period beyond 1975. However, neither schedule is complete at the present time.

b. Proposed Permittee-Lessee Geophysical and Geological Data Submission and Disclosure Requirement

The Department is considering amending the regulations issued pursuant to the Outer Continental Shelf Lands Act (OCS Act) with the objective of imposing new requirements with respect to geological and geophysical exploration under permits and pursuant to leases on the Outer Continental Shelf and the disclosure of information and data obtained by such exploration.

A public hearing was held on July 15 at the Department of the Interior Auditorium on geophysical and geological data submission and disclosure. Comments received by the Department are still being studied.

For a complete reading of the Department proposal, the reader is referred to the May 10, 1974, Federal Register notice on geological and geophysical data submission and disclosure which is attached.

c. Two-Tier System for OCS Leasing Area and Tract Selection

(1) First Tier

(a) Request for views of interested parties concerning areas of Resource Potential and Environmental Concern

On February 20, 1974, in the Federal Register, there appeared a request for comments from all concerned groups on potential Outer Continental Shelf (OCS) oil and gas leasing. The Bureau of Land Management and Geological Survey reviewed all the responses received and have determined several rankings of the 17 OCS areas that were delineated in the Federal Register Notice, on the basis of the responses. The Bureau received 63 responses, 25 of which were from oil or related industries. The remainder of the responses were from environmental groups, State and local governments and from private citizens.

In general, the oil companies responded with a ranking of the areas according to resource potential although a few companies also ranked the 17 OCS areas according to their individual preferences. Some of the companies, but not all, presented mapped data. Those which did so outlined areas of interest rather than individual geologic structures. Also some companies, but not all, gave estimates as to time periods required to achieve initialand peak production and identified factors that may be constraints to development in the OCS areas.

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Ranking according to environmental concern was requested in the Federal Register Notice; this particular request was not specifically directed toward the petroleum companies. Nevertheless, a few companies did submit a ranking according to relative degree of environmental hazard.

Specifically requested from environmental groups was a ranking of the areas according to enviromnental concern. None of the responses from environmental groups, however, presented this ranking. The consensus was that not enough information on the consequence of offshore development is available to make such a ranking. Likewise, the environmental groups which responded indicated that there is not sufficient information to indicate on maps specific environmental features or hazards. Instead, most of the responses called for increased study and analysis of the OCS environment before any decisions on leasing are made.

(b) Evaluation of Interior and other Federal Agency Reports on Rescurce Potential and Environmental Concerns

Responses were received from the following Bureaus within the Department of the Interior regarding offshore areas: 1) United States Geological Survey, 2) the Bureau of Mines, 3) the Bureau of Outdoor Recreation, 4) the National Park Service, and 5) the Bureau of Sport Fisheries and Wildlife. Responses were received from the following Federal agencies: 1) National Oceanic and Atmospheric Administration, 2) Department of Defense, 3) Federal Energy Administration, and 4) Federal Power Commission. In addition, the Council on Environmental Quality's report on environmental considerations in the Atlantic OCS and the Gulf of Alaska, ordered by the President in April 1973, was released in April 1974. The reader is referred to the CEQ study for their assessment of environmental impacts on the Atlantic and Gulf of Alaska OCS.

In addition to the Request for Comments that appeared in the Federal Register, the Bureau of Land Management requested resource reports from the aforementioned Bureaus within the Department of the Interior. In the request for resource reports, these Bureaus were asked to submit comments and data on their respective areas of concern.

The USGS prepared a report on the structure and resource potential of each of the OCS areas. The United States Geological Survey has estimated (March 1974) that offshore petroleum recoverable resources in the OCS to 200 meters water depth as yet undiscovered total 50 to 116 billion barrels. Undiscovered recoverable gas resources are estimated to be 355 to 710 trillion cubic feet.

The Bureau of Mines prepared an analysis of the supply and demand of petroleum until 1980. It is predicted that the demand for oil in 1980 will be 20.8 million barrels per day and for gas 34.5 trillion cubic feet per day. However, supply is estimated at 11.7 million barrels per day and 20.4 trillion cubic feet per day. These projections were made, of course, before Project Independence and the recent directive by the President to accelerate the OCS leasing program. In the present day tight petroleum supply situation, markets for petroleum are characterized by greater demand than supply. Depending on location of resources, certain patterns of processing and consumption likely would develop. That is, oil production from the Atlantic OCS would most likely be processed in refineries along the Atlantic seaboard and consumed in nearby eastern States. Likewise, gas from the Atlantic OCS would also be consumed in these areas. Similarly, production in the Pacific OCS would probably be processed and consumed in the Pacific seaboard and adjacent States. Increased oil production in the Gulf of Mexico is expected to be refined in Gulf coast refineries as is currently being done. Because of past activity in the prolific Gulf of Mexico hydrocarbon areas, an extensive network of pipelines carries hydrocarbons to many areas of the country. Gulf of Mexico hydrocarbons serve 36 of the 48 coterminous States. Presumably some of the increase in production that would result from accelerated activity in the Gulf of Mexico within a few years will serve to satisfy the increased demand for petroleum in Gulf Coast States, but the remainder will likely be piped to the other States that depend on Gulf of Mexico oil and gas. Alaskan production probably will be processed on the Pacific seaboard for consumption in Pacific and western States.

The National Park Service, the Bureau of Outdoor Recreation, and the Bureau of Sport Fisheries and Wildlife have categorized according to location some of those historic sites, national park areas, refuges, fishing areas, etc., that would be impacted by hydrocarbon activity. These reports have noted that the possible oil and gas lease sales in OCS areas represent many potential threats to the recreation environment. These reports assume a constant threat of damage from oil leakage or spills. The report also observes that construction of pipeline terminal stations and related road and facilities could eliminate some future opportunities for water-oriented outdoor recreation. They note that platforms and rigs visible from shore can have negative visual impacts and that their construction and operation may result in oppresive noise or objectionable odors.

Besides the resource reports requested from other Bureaus within the Department, the Bureau of Land Management contacted other Federal agencies for their responses to the questions asked in the Federal Register notice. The agencies contacted were: 1) the

Department of Commerce, 2) the Department of Defense, 3) the Department of Transportation, 4) the Department of Treasury, 5) the Environmental Protection Agency, 6) Federal Power Commission, and 7) the Federal Energy Administration. The Council on Environmental Quality report on the environmental effects of OCS development on the Atlantic and Gulf of Alaska OCS areas was transmitted to the Department during the same period that other agency comments were requested. This report is now being reviewed in detail. The following is a summary of responses of other agencies received by the Bureau of Land Management.

The National Oceanic and Atmospheric Administration (NOAA) (Department of Commerce) has provided data gathered in relation to fisheries in the Gulf of Mexico, the South Atlantic and the Pacific. In these reports, they call for the following specific actions to preserve fishing resources from potential damage from hydrocarbon development activities. All of these actions have been implemented or are being considered by the Department.

1. Wells and platforms should not be located in coral reef areas.
2. Platforms should not be located on steep slopes, as these are prime fishing areas for species such as snapper and groupers.
3. Drill cuttings and muds should be discharged so as to settle outside areas of productive benthic assemblages.
4. Submerged wellheads should be capped below the surface of the ocean floor or well marked with buoys.

5. Wells should be spaced far enough apart to permit trawling operations in the area.
6. All construction debris should be removed and disposal should be onshore.
7. Pipelines to onshore facilities should be consolidated into pipeline corridors.
8. Pipeline corridors should be located so that they do not traverse estuaries or that they traverse the least sensitive estuarine area. Productive bays and marshes should not be disturbed.
9. Pipelines should be buried beneath the ocean floor. Where they cannot be buried, they should be well marked with buoys and all buoys must be maintained.
10. In areas where obstructions already exist on the bottom, wells should be located near the obstructions to reduce further loss of fishing grounds available to the trawl fishery.
11. Onshore facilities must be located outside productive estuarine systems.

In addition, NOAA recommended that in order to preserve unspoiled water environments, there should be no haphazard array of development sites. Rather, the sites of hydrocarbon activity should be arranged, to the extent possible, in small clusters separated by no less than 50 miles. NOAA observed that density greater than this will increase the severity of effect upon fisheries and other marine estuarine resources.

The Department of Defense stated a preference for reviewing each leasing proposal on a case-by-case basis as they have done previously. Therefore, DOD did not wish to issue a commentary that would be inclusive of the entire OCS.

The U.S. Coast Guard (Department of Transportation) made the following comments in regard to OCS leasing. The Bureau of Land Management should avoid leasing in navigation routes but if necessary, consideration might be given to relocating such things as traffic separation schemes and ocean dumping areas where feasible and reasonable. The response from DOT mentioned that there are fishing areas listed in the Code of Federal Regulations, but it appears that there is no regulation to isolate the fishing areas from the leasing of oil and gas properties.

The Federal Power Commission discussed what they consider may well be the primary policy question to be decided with respect to future OCS leasing programs. This question is whether to focus attention on the frontier area of greatest potential i.e., Alaska, or to lease acreage in each of the major offshore areas with the goal of obtaining a more diffuse supply. To develop the Alaska OCS may be the most economically efficient method but, if the areas for development are more diverse, the Nation will have a more assured supply of petroleum. In regard to environmental protection, the FPC called for greater cooperation among agencies and advanced planning to reduce potential conflict between environmental protection and oil and gas activity.

(2) Second Tier

(a) Public Notices Identifying Permittee-Lessee Geological and Geophysical Data Reports for Potential Leasing Areas.

It is proposed that a public notice be published prior to the selection of tracts which would call for all geological and geophysical data that is to be disclosed as discussed above.

(b) Call for Nominations for More Specific Areas.

The general areas for leasing on the Outer Continental Shelf (OCS) are selected by the Bureau of Land Management (BLM) and U.S. Geological Survey (USGS). After the general areas are selected a call for resource reports from the various government agencies that have interests in OCS activities follows. The resource reports identify particular areas on the OCS that need to be withdrawn because of the potential danger to the environment and/or resources such as marine life, defense considerations, recreation, etc. At the same time that resource reports are requested, a call for nominations is published in the Federal Register; this is a formal request to industry and the public requesting which tracts they would like to see the Government offer for leasing. These tracts are in the general area that was selected previously. After the particular tracts are nominated, BLM-Washington Office (WO) and GS-WO review the nominations.

(c) Request for Views of Interested Parties Concerning Resource Potential and Environmental Concerns for More Specific Areas

Industry, Federal and State Government agencies, and the public are requested to respond on the resource potential and environmental concerns. It is hoped that these comments will assist the Department in evaluating the proposed area to be leased, and also to focus on potential problems that might be encountered if the area is leased.

(d) Tract Selection

BLM-WO and the USGS-WO select the general area where a sale will be held; the BLM field office selects the final tracts in the general area where the sale will be held. In the selection process, BLM considers: (1) prior tract leasing history, (2) industry nominations, and (3) the need to develop areas in a manner which still insures future availability of oil and gas resources. Accordingly, the Geological Survey considers: (1) request of companies that have presented technical data for GS inspection and evaluation, demonstrating the necessity for further development, (2) leasing in a manner which will insure development of geologic structures and trends, and (3) tracts most promising for development.

Prior to tract selection, BLM and USGS must insure that operating orders have been developed for the geographic region under consideration and that operating regulations and inspection programs have been instituted to assure compliance with environmentally safe equipment and operations.

C. Description of OCS Oil and Gas Operations

All of the material in this section was paraphrased or excerpted from the following: Kash and White (1973); Geer (1973); Savit (1974); Brewer and Shrum (1973, and testimony of L. G. Otteman and G. C. Lee at Environmental Hearing, Louisiana Offshore Lease Sale (OCS Sale #36), New Orleans, Louisiana, June 5, 1974.

1. Oil and Gas Operations

a. Geophysical Exploration

The principal tool of the geophysicist is the reflection seismograph which transmitss waves of energy into the earth's crust. They bounce off layers of buried rock, travel back to the surface and they are picked up by sensitive receivers and recorded on magnetic tape. These tapes are processed by computers and the final results are cross-sections as well as contour and isopach (interval thickness) maps which the geologists and geophysicists can use to locate areas and structures most likely to contain commercial oil and gas deposits.

(1) Energy Source

Before 1966 marine seismic surveys used dynamite as an energy source. Concern for personnel safety, potential damage to marine life and the high cost of dynamite prompted the development of alternate energy sources. Exxon's sleeve exploder - a method of detonating a gas mixture in an expanding rubber sleeve - was placed in operational use in 1968. Since then, other energy sources (sparkers, air guns, gas guns, etc.) have been developed and today account for more than 95% of the marine seismic energy source.

(2) Data Collection

Energy pulses reflected from underlying formations are picked up by detectors towed behind the surveying vessel and recorded on magnetic tape for processing into usable information. Usually receivers are spaced along a single cable towed by the surveying vessel. These receivers can be tuned and/or beamed to emphasize the seismic signal and de-emphasize boat-generated and other water-borne noises.

By use of a detector attached to a buoy containing a radio transmitter, sonic velocities through the underlying formation can be determined, thereby aiding the geologists and geophysicists in their interpretations of the reflection seismic data.

(3) Navigation Systems

During marine seismic surveys it is important to be able to reference the seismic data with surface location. The most advanced navigation equipment is sought for use by the seismic survey vessel. This equipment includes both satelite and long range shore-based (Loran -C) systems which allow the ship's position to be known within a few hundred feet. Loran -C has an estimated accuracy of 50 feet 200 miles from shore.

(4) Data Processing

Originally, seismic records were multiple traces on long film strips which had to be "read" by the geophysicists and interpreted into the final map and cross-sections.

Modern, computerized methods read and digitize the data as received and record it on magnetic tapes. During processing, further extraneous signals (echos, ringing reverbrations, etc.) are electronically filtered and a true seismic portrayal is displayed for the interpreters.

b. Exploratory Drilling

The exploratory or "wildcat" well is the final step in the determination of whether or not an oil or gas accumulation exists at the location chosen by the geologist and geophysicists. Since the purpose of the exploratory well is to first verify the existence of oil or gas and secondly to determine the extent or size of the accumulation, a prime requisite of the drilling rig is that it be mobile.

(1) Shallow Water Drilling Equipment

The most commonly used wildcat drilling rig for water depths up to 300 feet is the "jack-up" rig. This rig, with the legs raised, is towed from location to location. Once on a new location, the legs are jacked downward to contact the seafloor and the hull with its drilling equipment is raised approximately 50 feet above the surface of the sea.

(2) Deep Water Drilling Equipment

Beyond the 300 feet water depth, the semi-submersible rig and the drill ship are the two types of equipment used to drill exploratory wells.

The semi-submersible can displace as much as 20,000 tons and some are even self propelled. Once on location they are anchored in place and partially submerged. This submergence adds to the overall stability of the unit and greatly reduces the amount of "heave" (the up and down motion). Because of these better stability characteristics, the semi-submersible is usually preferred over the drill ship.

The drill ship, as the name implies, is a ship with a drilling derrick mounted midship and hole through the hull through which the drilling tools are lowered. The drill ship is self powered and has better seagoing characteristics than the semi-submersible.

The choice between a drillship and a semi-submersible depends upon many factors such as: expected weather conditions, depth of hole, expected frequency of moves, distance between moves etc.

Both the drill ship and the semi-submersible can be held in place directly over the location by dynamic positioning. This system can be used whether or not the drilling vessel is moored. Dynamic positioning or automatic station keeping is achieved by use of a sonar transmitter located either onboard or on the seafloor (if located onboard, then designed reflectors are placed on the seafloor), hydrophones, an on board computer and as many as a dozen small thruster motors spaced around the periphery of the drilling vessel. The sonar signal (either direct or reflected) is received by three shipboard hydrophones and fed to an onboard computer which then displays the ships position relative to the wellbore and the ships position can be corrected either automatically or manually by manipulating the mooring lines and operation of the thruster engines. Currently (July 1974) Shell is drilling in 2150 feet of water offshore from Gabon, Africa using the drillship SEDCO 445.

The developers now working on a tension-leg-platform (TLP) claim mobility as one of its assets and propose to use it for exploratory drilling. The TLP is described in detail in section C.1.c.

(3) Drilling Operations 1/

Once the wildcat rig is on location and either jacked up, moored or dynamically positioned and provisioned, drilling

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1/ Operations described in this section are oriented to Gulf of Mexico OCS operations because that area has been under development for some years and is where much present technology has been developed and where new technology is being worked on.

operations commence and these operations are basically the same regardless of the type of rig.

The first operation is to set the first string of pipe called "drive pipe", which is usually about 30 inches in diameter and is literally driven into the subsoil as much as 100 feet depending upon the structural integrity of the surface sediments. Next must be installed a drilling riser--a specialized string of pipe extending from the well head to the floating vessel. The riser must be flexible to allow for some movement of the drilling vessel; the riser is tensioned at the top to maintain its structural integrity. In deep and rough water the tension requirements may be reduced by equipping the riser with buoyant material. It is expected that buoyant risers can be designed for 3000-foot water depths within the current practical tensioner limits. The riser is essential to the drilling operation in that it provides for the return flow of the drilling mud and suspended cuttings.

Next is the installation of the blowout preventers stack (BOP). The blowout preventer, as the name indicates, is the first line of defense against a blowout or uncontrolled flow from a drilling well. Blowout preventers are of two basic types: 1) the bag type seals off anything in the hole by inflating a large rubber ring between the object and closing the hole. It is possible, but not recommended, to close the open hole with a bag-type preventer.

The other blowout preventer is a ram-type. This preventer can be equipped with different types of rams viz: 1) blend rams close across the open hole, 2) pipe rams close around the drill pipe or tubing whichever is in the höle and 3) shear rams which can cut through drill pipe if necessary. These blowout preventers are essentially large, powerful, fast acting, hydraulically operated valves. The blowout preventor stack usually is located on top of the drilling riser and just under the drilling floor; however BOP stacks have been developed for installation on the seafloor between the drive pipe and the drilling riser. These BOP's are remotely operated, close in less than 10 seconds and can be used in any water depth.

The description of drilling operations are identical with those for Development Drilling in the next section C.1.c.

Exploratory drilling on the OCS by mobile rigs is regulated and inspected by the USGS and the Coast Guard. The scope of these regulations include personnel safety, equipment, rig power systems, pollution control procedures, casing setting procedures, mud program, and drilling safety equipment. Failure to comply in any of these items can result in suspension of rig activity until corrections are completed.

(4) Wildcat Well Completion and Abandonment

Should the initial test be dry, the well usually is plugged and abandoned. Cement plugs are set to confine formation fluids in their present subsurface formations to prevent them from intermingling and prevent flow to the surface. During plugging operations well control equipment (BOP's) remains in use; the casing is cut off at least 15 feet below the mud line; all obstructions are removed; and the bottom dragged to be sure no obstructions are overlooked. In some cases it may be necessary to drill several exploratory wells before condemning a prospective area.

If well tests show that commercial quantities of natural gas or oil have been found, it may be necessary to do several additional confirmation tests before the company is satisfied that the reserves will support a development drilling and well completion program.

It is also important to delineate as precisely as possible the extent of the petroleum reservoir because of the extreme expense of deeper water platforms and the economic necessity of drilling as many production wells as possible (sometimes over 30) from a single platform. Platform location in relation to hydrocarbon deposits must be extremely accurate to minimize the number of platforms installed.

If petroleum deposits prove to be commercial, one of two courses of action may be followed:

(a) The exploratory well may be deemed expendable and be permanently abandoned. Procedures followed would be the same as above for a dry-hole abandonment.

(1) (b) The well may be deemed useful as a future production well and temporarily abandoned. In this case, a mechanical bridge plug is placed in the smallest string of casing and the well head capped and left for future entry when production activity commences. This results in the temporary existence of an underwater "stub". The Coast Guard District Commander requires that such stubs be marked by a buoy at the surface if located in 200 feet of water or less, and that the buoy be lighted if located in 85 feet of water or less.

c. Development Drilling, Production and Workover

(1) Platform Installation

Offshore drilling and production operations are usually conducted on fixed, bottom founded, water surface-piercing platforms. If exploratory efforts are successful in proving a hydrocarbon reserve, production operations are initiated by installing platforms to serve as a base for drilling development wells and for subsequent production operations. A number of wells may be directionally drilled to develop a large area from a single platform. Some platforms in the Gulf of Mexico OCS contain as many as 30 wells.

Appropriate design procedures are outlined in API Recommended Practice RP 2A and various API specifications. These guidelines have been prepared to cover engineering design and operation of offshore structures and related equipment. USGS OCS Order No. 8 defines regulatory approval procedures for platform design and installation.

Platforms have been installed in the Gulf of Mexico in water depths to 373 feet, and technology exists to extend platform operations to much greater depths. Platforms are now being fabricated for installation in the North Sea in water depths to 500 feet. A design for installation in 850 feet of water at the Santa Ynez Unit in the Santa Barbara Channel has been completed and is ready for implementation and a design for a 1020 foot platform for the Gulf of Mexico is underway.

The major difference between current operations and deep water platform installations will be the offshore erection techniques. In typical Gulf of Mexico template type structures, the lower portion, or jacket, is barged to sea, launched, upended and secured to the sea floor with piling driven through the legs. The deck section is then lifted into place and secured by welding.

Because of the large size of a platform for 800-1200 feet of water, the lower portion could be fabricated onshore and barged to sea in two or more sections. At least two methods have been devised and determined to be practical using current construction equipment for fabricating and installing multi-section structures. The proposed 850-foot water depth platform designed for Santa Barbara Channel will have two sections joined at sea in a horizontal position. Then the structure will be upended by controlled flooding, set on bottom and secured with piling. The deck section will be set in place in a conventional manner.

In a second method, being developed for the Gulf of Mexico, the lower jacket portion will be built in three sections. The base section will be launched and placed on bottom with derrick barges then secured with piling. The upper two sections of the jacket will then be set successively in place atop the base. All three sections will be joined by cementing a large tubular member inside each of the platform legs. Finally the deck section will be installed in a conventional manner.

Buoyant towers have potential applications in water depths greater than about 1000 feet. These towers would be pivoted at the base and stabilized in a vertical position by bouyant chambers. Unlike conventional platforms, buoyant towers should sway under the action of wave forces instead of resisting them. In waters much less than 1000 feet deep, however, the sway of these towers would be excessive. Towers that would support two drilling rigs, production equipment, and 40 to 60 wells appear feasible for water depths between 1000 and 2000 feet. This type drilling platform has never been used on the U.S. OCS.

Another concept--the "tension leg platform (TLP)"--is nearing the model testing stage. This platform will be tethered to the bottom by cables attached to anchors, deadweights or grouted pilings on the sea floor. Just below the water surface is a buoyant section designed to maintain constant tension in the legs and support the working platform and its load above the water surface. The net effect is supposed to be a "tower" that will provide a stable working surface without presenting a rigid, inflexible structure against the forces of the sea. A one-third scale model (triangular 120 feet on a side) is scheduled to be tested in 150 feet of water near Catalina Island next year (1975). If the concept proves feasible, this "tension leg platform" would be used in water depths deeper than 600 feet. Maximum depth for this type platform has not been determined but it is expected to be in excess of 3000 feet. Also, this type platform should be more economic than standard platforms because incremental cost for deeper water is only the cost of mooring cables (the "tension legs"). The TLP should also be somewhat mobile, sufficiently so, claims the developer, that it may be used in exploratory drilling.

In some areas of the Gulf of Mexico OCS, unstable bottom conditions exist (II.A.2.a.(5)). In these areas special design and installation techniques are used to assure a stable and safe structure. This consists primarily of; using fewer but stronger upright members through the unstable zone, jetting the entire template structure through the unstable sediments and driving piling well into the underlying competent subsoil.

In the arctic regions special precautions must be exercised to overcome the crushing and abrasive effects of ice. Very generally, structures in this environment have fewer but larger and stronger vertical columns through the ice zone. The members that do pass through the ice zone have extra wall thickness of specially treated steel to resist both the crushing forces and the abrasive wear of moving ice.

In the Gulf of Alaska and Pacific areas, seismic activity is of major concern. Techniques used to design large office buildings have been expanded to apply to offshore structures.

(2) Development Drilling

The drilling rig, power plants, generators, living quarters, storage sheds and other components, constructed in modular form, are added to the platform, and production well drilling commences. Equipment anticipated for use on deep water platforms is similar to that being used safely in current shallow water operations, and will be installed and operated in accordance with safe practices accumulated from industry experience. These practices form the basis of USGS OCS Order No. 8, which gives the safe practices a regulatory mandate. This order specifies multiple, redundant controls and safety devices including safety shut-in valves, high-low pressure pilots, high-low level controls, high-temperature shutdowns, gas detectors, shielded ignitions, fire prevention and detection equipment, and pressure relief systems. Drain and sump systems are also designed to collect any spillage that might occur on the platform.

As with exploratory drilling, the casing and mud programs for each development well must be approved by the Geological Survey before a drilling permit is issued.

To describe the drilling process certain simplifying assumptions must be made. These assumptions are that the well will be:

(a) a development well (not exploratory)

(b) drilled from a multi-well slot platform using a standard platform mounted rig

(c) a "normal" well, i.e., one in which no special drilling problems or mud problems are experienced which would cause an abnormal volume of cuttings or usage of mud

(d) drilled to a total depth of 15,000 feet.

The casing program for this well consists of five strings:

(a) the structural casing, (drive pipe) is usually 30 inches in diameter. It is set to a minimum depth of 100 feet to provide stability in unconsolidated sediments

(b) the 20-inch conductor pipe, set at 900 feet

(c) the 16-inch surface casing, set at 3,500 feet

(d) the 10 3/4-inch intermediate string, set at 10,000 feet

(e) the 7-inch production string, set at 15,000 feet.

In drilling, two distinct, important pressures must be considered. One is the pressure within the geologic formation penetrated and the other is the pressure required to fracture or allow the drilling fluid to enter the formation below the last casing string and above the drill bit. These pressures are naturally occuring phenomena. A drilling plan calls for maintaining a sufficient hydrostatic gradient to prevent formation fluids from flowing into the wellbore. This is done by adjusting the density or weight of the drilling fluid or "mud" that is continuously circulated through the drill string to provide pressure control. In addition to pressure control, the drilling mud has several additional important functions:

(a) it must be viscous (thick) enough to carry drill cuttings to the surface,

(b) it must be able to keep drill cuttings and weight materials in suspension when circulation is stopped,

(c) it must be able to release drill cuttings from suspension at the surface,

(d) it must form an impermeable cake on the wall of the hole to prevent loss of drilling fluid to low pressure formations,

(e) it cools and lubricates the bit and drill string, and

(f) it must allow electric and radioactive logging instruments to "read" through to the formation without masking the results.

The following table (Table 1) indicates the amount and kind of commercial mud components required in the drilling of this "typical" well.

In spite of considerable research, it is still not always possible to predetermine the formation pressure and the fracture pressure that the wellbore will encounter. This is particularly true in the case of wildcat wells. During drilling there are several means of determining the trend in pressure. They include measurements such as formation temperature (as evidenced by the temperature of the returning mud), shale density and changes in the penetration rate of the drill bit.

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Table 1. MUD COMPONENTS USED IN SEAWATER-LIGNOSULFONATE SYSTEMS TO 15000 FEET AND DRILL CUTTINGS REMOVED FROM 15000 FOOT WELL 1/

	INTERVAL-FEET				TOTAL
	0-900	900-3500	3500-10,000	10-15000	15000 Feet
Mud Components - Thousands of Pounds					
Barium Sulfate (Barite)	3	3	529	625	1160
Bentonite Clay	10	10	36	9	65
Attapulgite Clay	5	5	-	-	10
Caustic	0.5	0.5	20	23	44
Aromatic Detergent	-	1	2	-	3
Organic Polymers	-	1	3	-	4
Ferrochrome Lignosulfonate			26	69	95
Sodium Chromate				2	2
Total Mud Components	18.5	20.5	616	728	1383
Drill Cuttings					
Hole Diameter (inches)	24	18	13	9	-
Volume of Cuttings (Barrels)	504	843	1100	405	2852
Weight of Cuttings (Thousand Pounds)	408	680	890	328	2306

1/ It is emphasized that these are "typical" values for the Gulf of Mexico OCS. Quantities may vary as much as 50% from well to well within this area and by even more between major areas of the OCS.

If the hydrostatic gradient of the drilling fluid becomes less than formation pressure, a "kick" of gas or other fluid may enter the wellbore from the formation being drilled. The influx displaces some drilling fluid, thereby causing reduction in the hydrostatic head in the annular space between the drill pipe and the borehole.

If the volume of the influx is not excessive, and a surface indication (increased mud tank volume) is observed, the unwanted influx of fluid or gas can be circulated out of the well by careful observation of well conditions and adherence to preplanned emergency procedures. From the record of a kick, the bottom-hole pressure can be determined and with this pressure known, the mud weight can be adjusted to provide the correct hydrostatic head for the safe continuation of drilling.

An uncontrolled kick is called a "blowout". Blowouts seldom occur and usually can be controlled by implementation of preplanned emergency procedures and actuation of the blowout preventers which are mounted on every offshore well during drilling.

Blowouts can occur downhole when a low-pressure formation fractures, and fluids from a higher-pressure zone flow into the fractured formation. Such underground blowouts, like surface blowouts, require the careful use of preplanned emergency techniques to regain control. Blowout preventers and other well-control equipment must meet the requirements of OCS Order No. 2. This equipment is tested on a schedule set by prudent practice, but not less often than regulations specify.

To ensure that adequate provisions have been made for safety and well control, the casing program and drilling fluid, or mud, program must be approved by the Geological Survey before a drilling permit is issued. Along with adequate casing, it is important that enough cement be spotted between the casing and the wall of the hole to seal off and isolate all sensitive geological formations such as hydrocarbon zones and freshwater sands, and to separate zones of abnormal pressure from those with normal pressures.

Blowout preventers on drilling wells and the redundant combination of wellhead valves and subsurface safety valves have proven effective in maintaining control of wells when the normal controlling devices (drilling mud and production regulators and chokes) have failed. Once shut-in, the wells can be reentered through either the blowout preventers or wellhead valve with drill-pipe or tubing to perform remedial work and bring the well back under control. This can be done if the blowout preventer or wellhead is on the sea floor the same as if they were located on a platform. Likewise, should a well get completely out of control and crater around and outside the surface casing so that the well could not be reentered, then an offset relief would have to be drilled.

As drilling progresses, the drilling mud is continuously circulated down the drill pipe and up the annulus carrying the drill cuttings from the bottom of the hole to the surface. At the surface the mud stream is run across and through a series of shale shakers, desanders and desilters to remove all the suspended solids (drill cuttings). The drill cuttings are discharged directly into the sea unless, of course, they should contain oil, in which case they are washed to remove entrained oil before discharging. The wash solution is retained and eventually shipped ashore.

The first 3500 feet of the well is drilled and two strings of casing set (900 feet of 20-inch and 2400 feet of 16-inch) using essentially seawater plus natural clay additives as drilling mud. At this point, after the casing has been cemented, the mud is so contaminated with cement that it is (the mud) discarded by dumping it into the sea, after first removing most of the barite by centifuging. The amount discarded could be as much as 1500 barrels of mud, depending upon the amount of cement contamination.

At this point the system is converted to a ferrochrome lignosulfonate mud and used to drill the remainder of the hole and set the other two strings of casing. As shown in the preceeding table, the mud now requires more and more weighting material (barite) to maintain pressure control, bentonite clay for gel strength, caustic for pH control and ferrochrome lignosulfonate for viscosity control. During the drilling process some excess mud is acquired while trying to balance it (the mud) for the desired properties and some is lost overboard entrained with the drill cuttings.

After the well has been drilled to total depth and before the production casing string (the last) is run, several electric and radioactive measurements are made in the wellbore. These measurements are made by special instruments lowered into the well. A continuous graphic log is created as the instruments pass each succeeding formation.

The last (production) string of casing (7-inch in this instance) is run and cemented after the well has been logged. The next step is perforating or "shooting" the interval to be open for production. This interval is chosen by "reading" the electric logs and deciding the location and thickness of the producing formation. Both the logging and shooting operations are performed with mud in the hole.

(3) Well Completion

(a) Conventional Platform

When the well is drilled, cased and perforated, the completion operation starts. At this point, the well is under control by virtue of the weight of the column of drilling mud; the blowout preventors, of course, are still connected and available to close in the well in case of emergency. Next, the tubing is run on a packer which seals off the annulus between the tubing and casing and above the perforations. After the tubing has been set on the packer and hung in the casing head and a mechanical bridge plug set in the top, all possible connections with subsurface formations (tubing, and all casing annulus) are checked and tested to be sure the well is completely shutin. When it is absolutely certain that the well is completely shutin, the blowout preventors are removed and the preassembled well head (the "Christmas tree") is installed and connected to the flow line and the well is completed.

(b) Subsea Completions

The basic component of a subsea system is an individual subsea well drilled with a mobile rig. The wellhead is located on the sea floor, and flowlines connect to a nearby platform. The wellhead valves are remotely operated from the platform and are designed to close automatically if required. Reliability and safety of these systems has been field tested on 114 subsea completions since 1962. Of these, 48 are in the Gulf of Mexico and 40 are off the California coast. Water depth ranges from "shallow" to 375 feet.

Subsea completions follow the same general step-by-step procedure as for conventional platform completions. Needless to say the entire process is considerably more sophisticated.

One type of subsea well uses "wet" trees which are exposed to the seawater. The "wet" tree equipment is relatively insensitive to water depth, and can be installed in deep water in the same manner as in shallow water. A "wet" tree which had been in service for over seven years was retrieved recently and found to be in excellent condition. Another more recently developed system is the "dry" system. Wellhead equipment is essentially the same as in a "wet" system, except it is housed in a dry, one atmosphere chamber on the sea floor. Flowline connection and maintenance work can be performed by workmen inside the chamber, in a normal atmospheric, shirt-sleeve environment. The workmen are transported to and from the chamber in a tethered, atmospheric diving bell which mates to the chamber, allowing completely dry access for non-divers. One such completion was made in the Gulf in 1972 in 375 feet of water and has been on production since. The chamber was re-entered successfully last year (1973) for routine inspection and maintenance, and found to be in excellent condition.

(4) Production Facilities

Platform located production facilities consist of gas-oil separators, oil-water separators, gas scrubbers, compressors, pumps, storage tanks, instruments and controls. That, of course, is an over-simplification for the myriad of pipes, tanks, pressure vessels, valves, motors, pumps, compressors. As mentioned in section I.C.1.c.(2), OCS Order No. 8 specifies multiple redundant controls and safety devices including safety shut-in valves, high-low pressure pilots, high-low level controls, high temperature shutdowns, gas detectors, shielded ignitions, fire prevention and detection equipment and pressure relief systems. Drain and sump systems are also designed to collect any spillage that might occur on the platform.

The production platform contains all the equipment and performs the same function as field gathering station does at an onshore location. The fluid produced from the well is some mixture of gas, oil and water in varying proportions. Depending upon the flowing well head pressure, this mixture may be subject to as many as three stages of gas-oil separation. The stage separation process recovers the driest gas and the largest volume of liquid.

The gas may be further processed through scrubbers to remove any entrained oil, water or other impurities before it is compressed and sent ashore by pipeline. If there is insufficient gas to sell to a trunkline, it may be reinjected into the producing formation as a pressure maintenance measure, used for gas lift, used as engine fuel to drive pumps and compressors. Only on rare occasions is gas flared and then requires a permit from the OCS Area Supervisor of USGS.

The oil/water mixture that comes from the gas-oil separator goes first to a free water knock-out where the free water is separated by gravity from the oil. Should some water be emulsified with the oil, this mixture is sent through heater and/or chemical treaters to break the emulsion and separate the oil and water. The oil is pumped ashore by pipeline and the water is further filtered and treated and then disposed of overboard.

(5) Workover Operations

From time to time a producing well will require remedial maintenance (workover) for any one of a number of reasons. Many workover operations such as cleaning parafin, changing storm chokes and even replacing gas lift valves can be performed by pumping tools down the flowline and tubing. Major workovers require the use of a drilling rig to kill the well by circulating heavy mud, remove the well head, put on blowout preventors and perform whatever is required to improve or rehabilitate the well.

It is during major workovers when the remaining wells on the platform are still producing, that the risk of a major platform accident and/or fire is greatest. Because of these hazards, workover operations are carefully planned to keep wells from getting out of control as well as to prevent or minimize the release of oil to the environment. The Geological Survey is in the process of revising Gulf of Mexico OCS Order No. 8 to prohibit simultaneous production and drilling from the same platform. The restrictions will apply to workover operations as well as to drilling and producing operations. This revised order will probably be in effect by October 1974.

From the safety standpoint, completion and workover operations must be conducted carefully, and it is their critical nature that, in all likelihood, makes these operations safer than they otherwise might be. Operators of swabbing and wire-line units are well aware of the hazardous nature of their work and are extremely cautious. Despite the potential hazard, safety records during wire-line and swabbing unit work are excellent.

d. Transportation of Produced Oil and Gas

Oil produced on the OCS can be moved ashore either by a tank vessel (barge or ship or pipeline; gas, of course, can only be sent ashore by pipeline. As of 1971 only 3 1/2 percent of all OCS crude oil production was barged ashore; the remainder all came ashore in pipelines.

(1) Barges and Tankers

Tank barges are flat-bottomed vessels that may be self-propelled, towed or pushed. If they are towed or pushed, a sea-going tug is used as the power source. Tugs used for this purpose vary in size from 65 to more than 150 feet in length, and are powered by 350 hp to 4500 hp diesel engines. Although non-self propelled tank barges come in all sizes, three are most popular:

- 1000 ton capacity (7200 bbl.), 175 feet long, 26 foot beam, 9 foot draft.
- 1500 ton capacity (10,800 bbl.), 195 feet long, 35 foot beam, 9 foot draft.
- 3000 ton capacity (21,600 bbl.), 290 feet long, 50 foot beam, 9 foot draft.

One tugboat of 4500 hp is easily capable of pushing ten of the 3000 ton barges that are lashed together. Some barges are provided with a notch in the stern into which the tug may be fitted and secured; others are towed by being lashed to the port and starboard sides of the tug.

Self-propelled barges that may be used offshore have capacities ranging from 20,000 to 25,000 bbl. A 20,000 bbl. barge averages 200 feet in length, 50 feet in width and draws 9 feet of water; 25,000 bbl. barges are all relatively new, are only slightly longer (236 ft.) than their predecessors, but are the same width and draft. Larger 30,000 bbl. barges are under construction. All self-propelled barges and tankers must be inspected and certified by the United States Coast Guard. Power is provided by two

1000-1500 hp diesel inboard engines, each connected to a powerful screw which moves the barge at an average open water speed of 10 knots.

There are three basic barge designs: 1) single skin (hull), 2) double skin, and 3) barges having independent cylindrical tanks. Single skin tank barges have both bow and stern compartments that are separated from the midship by collision bulkheads. The entire midship shell of the vessel constitutes the cargo tank with structural framing inside. Double skin barges have an inner and an outer shell with the inner shell forming the cargo tank. This double skin structure provides added protection in case of collision, grounding, or some other mishap. Barges with independent cylindrical tanks are used for transporting liquids under pressure or where pressure is to be used to off-load the cargo; these will not be used for transportation of crude oil. In any case, barges usually do not have compartmentalized storage tanks.

The transfer of petroleum either into, or out of, a barge is a relatively simple operation. The vessel is docked either at an offshore platform or shore-based offloading facility usually with the aid of either an active rudder or a bow-thruster. Docking can be accomplished with relative ease in seas up to 5 feet. Once secured, hoses are connected to a manifold located on either side of the barge. These hoses must be equipped with a "quick-disconnect" apparatus in order to prevent a back flow from the hose from discharging into the sea. The coupler, because it may contain up to one-half gallon of oil, must have drip pans placed beneath it in order to catch any oil before it could spill into the water. The U.S. Coast Guard requires that a certified tankerman be present and on duty at the manifold during any oil transfer operations. After loading, or offloading, is completed, the transfer hose is drained dry by back flowing or draining the crude to the platform. The couple is then broken, and either a receptable is placed over the end to catch the drippings or the hose is plugged directly.

Loading of crude oil is usually done by means of a gravity feed system either from platform storage tanks or directly from the well. Offloading of crude to shoreside facilities is accomplished by pumps located on the barge or shoreside. The average rate of loading or discharge is approximately 4000 bbl./hr.

A tanker is a self-propelled ocean-going vessel that is compartmentalized into tanks for transport of liquids. Tankers are much larger than tank barges, the smallest used in crude oil transport is about 10,000 deadweight tons (dwt) or 65-70,000 barrels capacity. For use on the OCS, the size tanker that could be used would be limited by the allowable draft at its unloading port.

Barges and/or tankers may be used initially in the new areas until sufficient producing capacity is developed to justify a pipeline .

(2) Pipelines

Pipelines laid offshore are constructed and laid by several different methods, depending mainly on the size, location, intended use, and cost. One method, pipepulling, involves the use of barges and tugs to pull sections of welded pipe from an onshore launchway over the preselected right-of-way. These sections may either be dragged along the bottom or suspended by floats. There are at least three limitations to this system. First, an extensive section of shoreline, roughly perpendicular to the shore, must be available for the fabrication and launchway site. (Alternatively, it is possible although more costly to use a lauching jetty constructed from the beach out over the water.) Second, the total length of pipeline that can be laid is limited. One company estimates the limit to be 100,000 feet for smaller diameter pipe. Third, the pipeline right-of-way must be essentially a straight line. The pipe pulling method is not used often for laying pipelines to OCS locations.

Offshore pipelines, particuarly large diameter or long lines, are usually installed using a barge specially constructed for marine pipelining called a "lay barge". This barge is a self-contained unit including all of the facilities required to join the pipe by welding, cover the weld with protective coating, and to lower the pipe into place on the ocean floor. The pipe is coated on shore and delivered to the lay barge in uniform lengths or "joints" with the ends prepared for welding. Several anchors, at least two at each corner, are used to hold the barge in position. Joints of pipe are welded together on the deck of the lay barge to form a continuous length. When a weld is finished, inspected and coated, the barge is moved forward allowing the assembled pipeline to extend over the stern of the barge and to sag downward to lay on the ocean floor. A new length of pipe is added to the "forward" end of the pipeline and the process is repeated.

Making a high-quality pipeline weld requires a reasonable amount of time. Therefore to obtain rapid production, "assembly line" techniques are used allowing welding to take place at several stations simultaneously. To do this the work on the barge must take place in an almost level position. From the barge to the ocean floor the pipe will assume a double curve or "S" shape. If the pipe is too heavy or too stiff to reach the bottom unsupported a buoyant pontoon or slide called a "Stinger" is used to provide support for the upper section of the pipeline. To help support the weight of the pipe and to prevent buckling, a carefully controlled tension force is applied to the pipe by constant tension machines mounted on the barge.

The pipe assembly process utilizes the latest technology and the best welding techniques currently available. All joints are given a complete X-ray inspection for quality and then covered with corrosion resistant material prior to leaving the barge. Offshore pipelines are designed and installed to meet the same codes and specifications as onshore pipelines, such as API, ANSI, ASME, etc. After the line is completed, it is tested to make sure that it has been properly installed and will withstand the anticipated operating pressures safely. The pipe is further protected by cathodic protection systems to supplement the corrosion resistant coating.

For production beyond platform depth range (1200 feet), drilling must take place from floating drilling vessels and production accomplished using underwater wellheads on the ocean floor.

To handle the quantities required, offshore transmission lines have usually ranged between 24 and 36 inches in diameter. At the present time lines of this size extend to approximately 250 feet in the Gulf of Mexico. With existing equipment and utilizing current construction techniques, lines of this size can be layed to water depths of approximately 500 feet; however, both the pipe and the coating must be properly designed for strength and weight characteristics. A 32 inch diameter line will be layed on the North Sea in water depths up to 500 feet in the near future. Also in the same areas, a contract has been let for a 36-inch line in water depths of 540 feet for installation in the summer of 1975. Weather conditions in the North Sea are more severe than the

Gulf of Mexico; therefore, if these pipelines can be installed and operated satisfactorily in the North Sea, they should be practical for the Gulf of Mexico also. Large diameter transmission lines can be installed to platforms or terminals appropriately located adjacent to deep water production. To reach to the deeper water beyond the platform, one or more smaller lines can be used in place of the transmission line.

It is believed that present-day techniques and existing equipment currently in the Gulf of Mexico can lay pipelines of 12 to 18 inches in diameter to 1200 feet with only minor modifications. At the present time no lines approach this depth; the deepest pipelines installed in the Gulf of Mexico are in approximately 400 feet of water. When such deep water lines are layed the same proven methods and technology that are now used will be employed. Studies and designs made for areas all over the world, verify that installation in these depths is technically feasible.

Practically all large and intermediate size offshore pipelines are covered with corrosion resistant coating and a concrete coating. The purpose of the concrete coating is to add weight to hold the pipe in place on the ocean floor, primarily to resist currents. The additional weight makes the pipelines more difficult to install. Fortunately, bottom currents are less severe in deeper waters, particularly the currents associated with wave and storm action. This allows reduced weight coating for deep water, which simplifies installation.

Flowlines between platforms and underwater well heads could conceivably reach to water depths as much as 6000 feet (approximate depth of bottom of continental slope). These lines will range in size from 3 to 8 inches in diameter with a wall thickness relatively large compared to the diameter, which will provide good resistance to buckling and eliminate the need for weight coating. Both of these factors make the pipe more flexible and easier to handle. These flowlines can be installed with a lay barge using techniques similar to those previously described. However, for the deeper water ranges, it will probably be desirable to use an inclined "high angle" ramp that is adjusted so that the pipeline leaves the barge at the proper angle to reach bottom in a single curve or "sag" bend, similar to a cable held in a catenary. This eliminates the need for support from a stinger and reduces the stress on the pipe. The laying rate is reduced as fewer working stations are available. This procedure has been very thoroughly developed, but only limited applications have been made to date.

Holding the barge in position by anchors becomes more difficult as water depth increases, and moving anchors to allow the barge to progress along the pipeline route will be more time-consuming. If this becomes a problem, it may be desirable to provide auxiliary propulsion to assist moving the barge ahead and to counteract the tension which is applied to the pipeline. It may also be desirable to consider a "dynamic positioning" system similar to that used on some floating drilling vessels. This is basically a computer controlled, all-direction propulsion system to hold the vessel in a fixed position reacting to the effect of wind, wave, and current.

At the present time, it is the opinion of the industry, that it has the capability of laying 24-26 inch diameter pipe in water depths up to 500 feet; 12-18 inch diameter pipe in water depths up to 1200 feet, and 8 inch diameter pipe in water depths up to 2100 feet.

In depths under 200 feet present OCS administrative procedures requires burial of the pipelines. The minimum depth of burial is 3 feet except in shipping fairways and anchorage areas, where the minimum depth is 10 feet. Burial is effected by jetting sediment away from underneath the pipeline and allowing it to sink into the resulting trench. The equipment used in this operation consists of a work barge equipped with high volume/high pressure water pumps and air compressors. From the barge, a multiple membered towline consisting of a strength member, water line, and air line extends downward to a U-shaped structure which straddles the pipelines and glides along it on rollers. Affixed to the U-shaped jetting device are several nozzles which direct water and air, under high pressure, ahead and below the pipeline. Sediments are blasted out of narrow trench by the water jets, partially lifted by the air and deflected to the sides by various types of fins. The suspended sediments fall diffusely along either side of the trench. As the jetting device is pulled forward, the pipeline settles into the trench and is partially buried quite soon by the reworked sediment as it slips and settles back into the depression. Complete burial and restoration of original bottom contours may require additional time. In shallow waters, experience has shown that contour restoration to be quite rapid, whereas in deeper waters, more than a year may be required.

Even though a buried line is protected from fluid forces it is not necessarily stable. If it is too light, it will gradually work its way up through the soil and become exposed to the water forces. If it is too heavy, it will gradually sink in the soil and impose additional tensile stress in the line. Design procedures for determining the vertical stability of the line in sands and clays have been developed and are available in the industry.

Difficulties have been experienced in burying pipe in cohesionless sands. In this case the sand will often refill the jetted trench before the pipe can settle into it. Another method, fluidization of the sand, enables successful burial in this type of substrate.

To prevent corrosion, pipelines are carefully coated with such materials as epoxy compounds or thick asphaltic mastic. If extra weight or mechanical protection is needed, these, in turn, are covered with a layer of dense concrete. The lines are protected from electrolysis by both impressed-current systems and by sacrificial anodes (zinc is commonly used). Corrosion prevention measures are now required by 49 CFR Part 195. Although offshore pipelines are relatively inaccessible as compared to onshore pipelines, they nonetheless can be repaired by divers. Experimental dives have been made to 1,000 feet, but work at this depth is difficult and expensive. Methods of using submersibles to latch on to a subsea line and repair it with mechanical arms and special tools are under study and nearing the point of practical demonstration.

As in the case of workover operations, the expense of the pipeline installations, coupled with the catastrophic implications for the local marine environment should a major break occur, have combined to dictate a highly conservative design, emplacement, and operating philosophy.

As the pipeline construction approaches and traverses the shoreline, it is buried deep enough to avoid its being exposed by storm-associated beach erosion. From this point the pipeline construction will be extended toward a storage facility, wharf facility, or a major existing pipeline system, in turn leading to a processing facility, refinery, or interstate gas line.

b. Pipeline--Operation and Maintenance

The safe operation and maintenance of a pipeline system requires several redundant monitoring systems to ensure the integrity of the line and detect leaks. The primary leak detection system in use (required on all lines built after March 31, 1970 by 49 CFR Part 195.406 and 195.408) is a set of automatic pressure sensing recorders on both ends of each pipeline system. These devices are equipped to either shut down the flow automatically or sound an alarm to alert personnel of an abnormal pressure level. In this way, a leak of substantial rate is detected immediately. This system is insensitive to leaks which do not produce a decrease in line pressure greater than 300-500 psi. It is essentially a safeguard to prevent the escape of large volumes of oil due to a catastrophic line break.

The second system of leak detection is the routine patrolling of the offshore wetlands routes by boat or aircraft, and onshore by wheeled vehicle or aircraft. A minimum patrolling frequency of intervals between inspections not exceeding 2 weeks is required by 49 CFR Part 195.412, but in actual practice is performed more often. This type of monitoring would result in the detection of all sizes of leaks of course, but would be of little consequence in preventing the loss of a large amount of petroleum in the event a large line were severed. The appeal of a system of regular pipeline patrolling is that it allows detection of small leaks and therefore complements the pressure-sensing system described above. With the present day volume of airborne and waterborne traffic over the oil producing area of the Gulf of Mexico, it is considered highly improbable that any spill would go undetected for any appreciable length of time.

The third system for leak detection consists of a series of volume-recording flow meters on either end of a pipeline system. Because nearly all crude oil moves from OCS areas to shore by common carrier lines, it must be metered in the offshore pipeline gathering system and again at the onshore pipeline terminal in order that each producer be properly credited for his share of the common stream. The flow sensors continually measure input and output in real time; thus when attendant personnel record these readings for inventory control they are able to discover a decrease in output which would indicate the possibility of a small leak. This is usually done on a shift schedule, once every eight hours or more frequently.

One more safety feature which would be built into all pipelines resulting from this proposal, according to industry spokemen, is that remotely operated mainline block valves will be provided at remotely controlled pipeline facilities in order to allow isolation of segments of the pipeline. Isolating valves are required by CFR 195.260 and remote operation of these valves, which is now voluntary, would be one of the primary objectives of a remote controlled pipeline facilities. Table 2 shows the relationship between the diameter of a pipeline and the volume contained per mile of line.

Table 2. LENGTH/VOLUME RELATIONSHIP OF LINEPIPE

Size (inches ID)	Length Required to Hold 1000 bbl. (miles)	Barrels Per Mile of Line
2.067	45.6	22
4.026	12.0	83
6.026	5.3	189
8.071	3.0	334
10.020	1.9	515
12.090	1.3	750
24.000	0.3	2954

e. Offshore Storage

Crude oil storage on the Gulf of Mexico OCS is, in general, limited to small volume (10,000 barrels or less) tankage on production platforms. There are still a few isolated instances where barges are used as floating storage with the oil moved to shore in transport barges. Also there is one 100,000 barrel platform mounted tank in the Ship Shoal area.

The storage tank used in conjunction with producing platform operations must comply with the safety and pollution control regulations of OCS Order No. 8 and specifically must be equipped with high-level shut-in sensors.

f. Timetable for Development of OCS Oil and Gas Leases

The length of time required to develop an OCS oil and gas lease is dependent upon many factors, some of which are:

(1) water depth

(2) distance from other producing fields

(3) number and depth of development wells required to justify a pipeline

(4) availability of drilling equipment

(5) climatic conditions (storms, ice, etc.)

For development of leases in "normal" water depths (up to 400 feet) on the Gulf of Mexico OCS it takes between 4 and 5 years to prove the reservoir by exploratory drilling, to fabricate and erect one or more platforms and to drill 15 development wells on each platform. One operator has estimated that it may take 10 years to develop one of the "deep water" (1200-1800 feet) tracts; however, this estimate assumed that there would be some delay because of known shortages of material and supplies.

To generalize, production from a fixed platform in 400-600 feet of water should be available 3 to 6 years after a field has been discovered and its size determined--at least enough to justify investment in development. For fixed platforms in 1000 feet of water the time may stretch to 8 years. Production from underwater completions in 1000-3000 foot water depths should be available in the mid 1980's.

The technology to drill in 3000 feet of water exists today; however there are only a limited number of drillships with this capability available, and new construction requires up to two years from order to delivery.

Development of the environmentally hostile areas of earthquake zones, heavy moving ice fields and unstable bottoms would require additional study and thus, more time.

A general description of how platforms are designed for these areas is found in section I.C.1.c.(1).

g. Terminations of Offshore Oil and Gas Operations

According to industry estimates, with proper placement of wells and sufficient pipeline capacity, a gas reservoir could be profitably drained in as little as 10 years. In contrast, some oil reservoirs have been produced for over 20 years in offshore areas. When the reservoir has been depleted to a level where it cannot be profitably produced, operations are terminated. During abandonment, the wells are plugged with cement, the casing severed at least 15 feet below the mud line, the platform removed, and all obstructions cleared from the area. All that remains is the pipeline system. Frequently, major trunklines can be used for future oil and gas production from adjacent areas, but smaller spur lines are abandoned in place. Pipeline abandonment consists of first purging the lines of entrained hydrocarbons by water flushing and then severing the ends below the mud line.

2. Offshore Oil and Gas Development Technology

a. Existing Commercially Feasible Technology

(1) Geophysical Exploration

Geophysical exploration tools and techniques continue to be improved as new electronic and computer capabilities evolve. The latest breakthrough is the "bright spot" techniques which gives a better indication of the existence of high gas and/or oil saturation.

(2) Exploratory Drilling

(a) Shallow Water Drilling Equipment

This equipment is now greatly refined over the first offshore drilling rigs. New equipment, particularly the jack-up's are quite mobile--some even self-propelled--with up-to-date automation and safety features. Some of the rigs now being delivered can drill to 30,000 feet in 300 feet of water.

(b) Deep Water Drilling Equipment

Floating drilling equipment is of two types: drillships and semi-submersibles. The drillships are preferred for wide-ranging exploratory work due to their higher transit speeds whereas semi-submersibles have much better stability during the actual drilling operations.

Anchoring systems for both types of rigs were restricted to about 600 feet of water until recently. Many rigs currently under construction are being equipped with 1000 foot mooring systems. This same depth (1000 feet) is also about the current limit of diver capability.

As mentioned in I.C.1.b.(2) one rig is currently (July 1974) drilling in 2100 feet of water, using a dynamically positioned drillship. Present water depth limitation is thought to be about 3000 feet; the limiting factors being the design of the drilling riser and the electrohydraulic systems for safe and reliable control of the subsea well head blowout preventors.

(3) Field Development

(a) Platforms

Computer assisted design techniques are at a stage whereby industry claims it is prepared to design and build a 1020 foot platform; a platform for 850 feet of water has been designed and is ready to start construction as soon as a permit is issued. At the present time, the maximum water depth feasible for a fixed bottom founded platform is determined by economics more than any other factors.

In areas with unstable bottom conditions, industry has developed designs that will jet the entire platform sub-base or template through the unstable sediments and then drive piles through the legs into the stable subsurface. Other design improvements use fewer but stronger vertical members which offer less resistance to mud flows and other potential movement of the unstable areas.

(b) Drilling

(i) Shallow Water

Development drilling technology for shallow water OCS development is the same as onshore drilling technology and as described in section I.C.1.c.(2).

(ii) Deep Water

Development drilling technology for deep water is the same as described in I.C.1.b. and I.C.1.c.(2) with the depth limitations imposed by platform depths I.C.2.a.(3)(a) or subsea completion capabilities.

(c) Completions

(i) Platforms

Well completions on platforms are essentially the same as at onshore locations. After the well has been drilled, cased, logged and perforated, and the tubing run and hung in the well head, mechanical bridge plugs are run and set in the tubing to close in the well. The BOP's are closed and the pressure in the well bled off to check that the bridge plugs are holding and the well dead.

Once it is certain that the well is dead, the BOP's are removed and a preassembled well head array of valves, chokes, gauges etc (known as the Christmas Tree) is installed and connected to the flow line ready to produce. Wells completed on the OCS are protected by redundant safety systems of fail-close valves. The tubing head valves are held open by hydraulic pressure and are spring loaded to close if anything disrupts the hydraulic operating system. When tubing head valves are closed (they of course may also be operated manually) the well pressure is directed in such a way as to abet the spring loading and help keep the valve closed.

Another safety feature on each well is the subsurface safety valve. This device is located in the tubing, well below the elevation of the sea floor; the original ones were designed to close automatically when the producing rate exceeded a preset value. These "storm chokes" are subject to the cutting action of abrasive material, particularly in those wells which produce sand, and several failures have been reported. New completions are now required to use "Surface Activated Subsurface Safety Valves" which, like the well head valves, are kept open by hydraulic pressure controlled from the surface. Also, whenever the tubing is pulled from old wells during workover operations, the old storm choke is replaced with the surface controlled subsurface safety valve. Many OCS wells are also equipped so that some minor repairs such as parafin scraping, changing gas lift valves and storm chokes can be accomplished with tools pumped down through the flowline.

(ii) Subsea

Subsea completions are described in section I.C.1.c.(3)(b). The "wet" tree has virtually unlimited water depth capability. "Dry" or encapsulated trees are limited by the capability of the diving bell or utility capsule which is now about 1200 feet. Subsea completions have surface controlled fail-close well head valves and most are equipped for through-the-flowline workovers. Surface controlled subsurface safety valves for subsea completions are in later stages of development.

(d) Production

(i) Platforms

Platform located production facilities are described in section I.C.1.c.(4).

(ii) Subsea

At this time (July 1974) there are no subsea production facilities, i.e. separators, pumps and compressors, installed on the U.S. OCS.

(4) Transportation of Oil and Gas

(a) Pipelines

Pipeline construction is described in section I.C.1.d.(2). At the present time, it is the opinion of the industry that it has the capability of laying 24-26 inch diameter pipe in water depths up to 500 feet; 12-18 inch diameter pipe in water depths up to 1200 feet and 8 inch diameter pipe in water depths up to 2100 feet.

(b) Tankers and Barges

Tankers and barges which may be used on the OCS are described in section I.C.1.d.(1).

(5) Offshore Oil Storage

As mentioned in section I.C.1.e., there is very little offshore oil storage on the U.S. OCS, and no need or requirement is foreseen for new areas.

Underwater storage has been developed and installed in the Persian Gulf (three 500,000 barrel tanks) and the North Sea (a one million barrel tank). A floating barge of one million barrel capacity attached to a single point mooring in the Persian Gulf is used for floating storage.

(6) Oil Spill Prevention

(a) Drilling and Blowout Control

A blowout can occur when the formation pressure exceeds the weight of the mud column. If this over balance of the mud column is detected soon enough a blowout can still be averted by implementation of preplanned emergency procedures. This usually involves closing the blowout preventors and adding weight to the mud column by degassing and adding weight material, meanwhile circulating the mud under controlled pressure conditions.

Abnormal downhole pressures may be detected by monitoring the volume of mud in the tanks, change in drilling rate, or change in mud temperature. Systems are now available to monitor the mud tank volumes and temperatures directly at the drillers console. One other system that records pressures at the drill bit by impressing coded pulses on the mud column is now available commercially.

(b) Producing Operations and Workovers

The state-of-the-art of oil spill prevention on producing platforms is quite well developed. Automatic fail-close well head valves are available that can be actuated:

- manually
- remotely from several positions
- by high-low pressure sensors in flowlines
- by flame and smoke detectors

As a backup to the automatic well head valve there are also surface activated subsurface safety valves. Additional spill prevention is provided by the high-low pressure sensors and high-low volume sensors in separators, water knockouts and storage tanks. For workover operations, some of the repairs (paraffin scraping, pulling and replacing storm chokes and gas-lift valves) can be performed by tools pumped through the flowline (TFL) and thus obviate the necessity to kill the well, remove the tubing head vales and install blowout preventors--always a risky operation.

(c) Pipelines

Pipeline systems are protected by a set of automatic pressure sensing recorders in both ends of the system. These devices either shut down the flow automatically or sound an alarm to alert personnel of abnormal pressure levels. This is primarily a safeguard to limit the size of a spill in case of a catastrophic line break, since this detection system is insensitive to line pressure fluctuations up to 500 psi. Most oil is metered as it leaves the producing platform and again as it enters the onshore tank farm; thus attendant personnel can detect relatively smaller leaks by comparing inventory volumes (pumped vs. received) on a shift schedule, once every eight hours or more frequently.

Pipelines are also protected from corrosion by various coatings and by cathodic protective devices.

(7) Oil Spill Containment and Cleanup

(a) Containment

Oil spill containment capability is restricted to some type of a deployable boom arrangement. These systems are severely limited by wave height, wind velocity and current. Since one main factor in oil spill containment is time, some concessions in design and materials are necessary so the systems can be air deployable.

(b) Cleanup

There are two main cleanup techniques in use, mechanical gathering and sorbent recovery. The mechanical recovery systems are suitable only in calm water and work better on heavy viscous crude than they do on light crude or products. Sorbent clean-up consists of spreading a sorbent material on the slick, mixing it with the oil then recovering the sorbent/oil mixture and disposing of it by burning or burying. Straw is a commonly used sorbent material.

(8) Drilling Waste Disposal

The major drilling "wastes" are drill cuttings and drilling muds. The weight and volumes of drill cuttings produced while drilling a 15,000 foot well on the Gulf of Mexico OCS is given in Table in section I.C.1.c.(2) and amounts to about 1,000 tons per well.

The same table shows the amount of commercial mud additives used in the same well. In the case of an exploratory well that is plugged and abandoned, the hole is left full of mud (below, between and on top of all cement plugs), and after most of the barite has been recovered, the remainder is dumped overboard. On a multi-well platform, most of the mud is passed on from well to well; however, some mud is discarded overboard as each well is completed due to the need to recondition the mud occasionally.

b. Potential Future Commercially Feasible Technology

(1) Geophysical Exploration

The science- or art-of interpreting geophysical data is so highly competitive that new techniques do not become public knowledge until they are quite well developed. The latest innovation, the "bright spot" technique, now gives some indication of the content of underground structures. With continuing developments in electronics and computer sciences, it is not beyond imagination that the capability to define stratigraphic traps will eventually evolve.

(2) Exploratory Drilling

(a) Shallow Water Drilling Equipment

Present mobile shallow water drilling structures are adequate for all U.S. OCS areas except those with unstable bottom conditions and those with seasonal and/or moving ice conditions. In the case of areas with unstable bottom conditions, drillships or semi-submersible rigs could be used for exploratory work.

The actual drilling equipment is the same for onshore, shallow water and deep water drilling. New technologies that may be developed in the future are, mainly, improvements and refinements of present day practices. These include:

- longer lasting bits to reduce number of bit changes
- direct reading of formation pressures at the drilling bit
- improved mud monitoring systems that can measure a sudden gain or loss of as little as one barrel in a 3000 barrel mud system
- continued improvement in automatic drilling technology

The only radical departure from conventional drilling technology is an "Omnidirectional Drilling System" for which patents are pending but which has yet to be tested. To quote from the prospective patentee:

> "There is no possibility whatever of an oil leak into the water inasmuch as the surface of the subsoil, as the interface between the sea and the subsoil, is not pierced. The Omnidirectional Drilling System is a self-contained system capable of drilling along any curvilineas path and for any distance.
>
> The Omnidirectional Drilling System is able to drill for oil and natural gas in the subsoil of the sea directly from dry land without in way going through the sea itself."

(b) Deep Water Drilling Equipment

All of the discussion in the preceeding section I.C.2.b.(2)(a) apply also to deep water drilling equipment. In addition, the future will see improvements in the following areas to permit drilling in deeper waters:

- improved mooring systems
- improved riser support systems

- improved dynamic positioning systems
- improved reentry techniques and equipment
- improved control systems for the subsea well head BOP's

All of this should allow the present drill ships and semi-submersibles to move at least to the 3000 foot water depth area and perhaps deeper.

The Tension Leg Platform (TLP) is scheduled for sea tests in early 1975. The TLP will be a buoyant structure held in place by tensioned vertical-anchor cables. Buoyant vertical colums extending upward from submerged horizontal cylinders will support a working deck well above the water surface. The advantage of the TLP would be that the incremental cost for additional depth would only be the cost of anchor cable. Although being designed primarily as a development drilling and production platform, it could be used for wildcat drilling in deep areas.

(3) Field Development

(a) Platforms

Plans are now complete for a platform to be erected in 850 feet of water in the Santa Barbara Channel. Industry feels that it is possible to build a safe platform in 1200 feet of water in the Gulf of Mexico. The technology exists to design platforms for almost any water depth; the maximum feasible water depth is determined primarily by economics.

The TLP as described in I.C.2.b.(2)(b) appears to be a reasonable prospect as an economically justifiable deep water drilling and production platform for the near future.

(b) Drilling

All of the discussion in section I.C.2.b(2) pertains equally to this section.

(c) Completion

(i) Platform Completions

The basic systems and tools for well completion are not expected to change in the foreseeable future; however there will be a continuing effort to improve reliability of all parts of the system and thus improve safety standards. Future improvements in automation should also improve safety records by reducing the opportunities for human error.

(ii) Subsea Completions

As described in section I.C.2.a.(3)(c)(ii) subsea completion technology exists to about 1200 feet of water.

To go beyond diver capability (approximately 1000-1200 feet) with "wet tree" completions requires the development of automatic or remote operated flowline connectors. It is expected that this technology will be developed for 3000 feet of water before economic reserves have been proven at those water depths.

Encapsulated well completions are limited by shell thickness and strength of the capsule; all other parts of the completion are identical with platform or onshore completions and thus will profit from any advancements in those areas. One limitation again is the connection of flowlines beyond diver capability; however, with the encapsulated tree, there is the possibility of pulling the flowline through a packing gland to where the connection can be completed by non-diver personnel inside the one-atmosphere chamber.

(d) Production Facilities

(i) Platform Located

Improvements in platform located production facilities will follow the same trend as those for platform completions; the emphasis will be for more automation and more reliable sensing and detection systems.

(ii) Subsea Production Facilities

Some subsea systems are now either undergoing tests onshore or being prepared for installation and testing in shallow water. As these move into water beyond diver capability, they will require remote operated manipulators to switch wells for testing, directing TFL tools, operating pumps, compressors, etc. Gas compression and/or a two phase pumping system are two necessary components of a susbsea production system that have yet to be solved.

(4) Transportation of Oil and Gas

(a) Pipelines

New technology for pipelines will be directed toward faster and more economical lay barges and pipelaying procedures. It is expected that pipelaying techniques will advance into deeper and deeper water concurrently with drilling and completion capabilities.

(b) Tankers and Barges

The use of tankers and barges on the U.S. OCS is expected to be severely restricted and limited to transportation of small volumes produced while testing wells to determine size and extent of reserves before commencing a field development program. New technologies for tankers are, of course, advancing rapidly worldwide. Advancement is noticeable mainly in size but is equally progressive in the forms of double bottoms, segregated ballast systems and limiting the maximum size of individual tanks or compartments.

(5) Offshore Oil Storage

Like tankers and barges, there is little offshore storage anticipated for the U.S. OCS.

(6) Oil Spill Prevention

(i) Drilling

Many of the new technologies described in sections I.C.2.b.(2)(a)&(b) are directed toward well control and blowout prevention--thus are also oil spill prevention techniques.

(ii) Completions

Improvements in the reliability of surface operated subsurface safety valves as well as the fail-close tubing head valves will contribute to reduced oil spills.

(iii) Production Facilities

No radical departure from present production facilities is anticipated in the future. New developments will be in the field of automation and fire and smoke detection devices.

(iv) Pipelines

Improvements in the mass flow monitoring systems will allow faster response to a major pipeline break.

(7) Oil Spill Containment and Cleanup

No new technology is anticipated in the field of oil spill containment and cleanup.

(8) Drilling Waste Disposal

No new technology is anticipated in the field of drilling waste disposal. The only drilling wastes are drill cuttings and drilling mud. The only alternative to discharging these wastes into the sea is to haul them ashore and dispose of them there.

D. Other Management and Supervisory Aspects of the Program

1. Management Requirements Before Onset of OCS Operations

a. Preparation of Individual Sale Environmental Impact Statements

Each individual leasing proposal under the ten million acre program will require an environmental impact statement under section 102(2)(c) of the National Environmental Policy Act of 1969. The Bureau of Land Management will continue to prepare these statements using generally the same procedures as are currently followed. These procedures begin with the selection of a geographic area in which a lease sale is proposed to be held. Summary resource reports in that area are requested from the U. S. Geological Survey (USGS) and the Fish and Wildlife Service (FWS), and the National Marine Fisheries Service (NMFS). These summary resource reports are mainly used for tract selection purposes, but are also used as information sources for the draft impact statement. Other information sources (published literature, research in progress, contract research reports, and personal contact with scientists in the area) are utilized in preparing the statement. In general, the statements describe in considerable detail the physical and biological environments in the area (both offshore and onshore), the coastal socioeconomic conditions, the hydrocarbon resource potential of the sale, the primary and secondary impacts of the lease sale on the environment and economy, and a matrix analysis of each tract being offered for the possible impact of structures and oil spills that could ensue from development of that tract. After the draft impact statement is prepared and reviewed within the Department of Interior, it is made available to the public for a minimum of 30 days before a public hearing on the proposed action is held. Review and comments are specifically requested from the following Federal agencies:

Geological Survey
National Park Service
Fish and Wildlife Service
Bureau of Outdoor Recreation
Bureau of Mines
Environmental Protection Agency
Department of Transportation
Federal Power Commission
Federal Energy Administration
Atomic Energy Commission
Department of Commerce (viz. National Marine Fisheries Service)

Review and comment is also solicited from affected State(s) agencies, as well as being requested from any other interested parties. Comments supplied by solicited agencies, oral and/or written testimony from the public hearings, and other public comment are incorporated into the final environmental impact statement. Special emphasis is placed on identifying highly valued sites (e.g. shipwrecks, wildlife refuges, reefs) and habitats (fishing areas, marshes) that could be severely affected by normal operations or accidental oil spills, and on identifying specific problems that would increase the risk of exploration and development operations (e.g., unstable bottom conditions). These sites or problems may then be mitigated in several ways. The Secretary of the Interior may withdraw tracts from the sale, delay the sale, or impose special stipulations on operations in tracts located near highly valued sites or in problem areas. The final impact statement must be available to the public at least 30 days before the proposed action can be undertaken. A minimum of 90 days must elapse between the time the draft statement is made available and the time the action is begun.

For the detailed description of Federal responsibility in impact statement preparation (content, timing, purpose), see the guidelines published by the Council on Environmental Quality in the Federal Register on August 1, 1973 (Volume 38, No. 147, Part II).

b. Pre-Sale Evaluation

The U.S. Geological Survey calculates the resource value of each OCS tract with BLM performing an audit and review function. In calculating the resource value for each tract, GS is responsible for collecting and analyzing geologic, geophysical, and engineering data which may be either purchased from contractors and/or obtained from industrial sources. The data analyzed by GS is then fed into a computer program that yields a mean value that has been generated by a range of values method. The various parameters include a minimum, maximum, and most probable of the following which varies between individual tracts: productive acres, oil acre ft./total acre ft., gas reservoir life, oil reservoir life, net pay (ft.), recovery factor-oil (fraction of oil in place (OIP) or stock tank barrels (STB/acre ft.)), initial STB/day/stream, initial MCF/day/stream, years to production, gas-oil ratio standard cubic feet (SCF)/STB, STB condensate/MMSCF. The following parameters were assigned a constant minimum, maximum, and most probable value for each tract: $/STB (except for drainage tracts), current $/MCF, tax as a fraction of gross income, inflation factor for operating costs (1972=1.0), value is used for each tract for porosity, water saturation, and oil formation volume factor as bbl./STB.

The above values assigned to these parameters are fed into a range of values (ROV) computer program: the ROV will generate 500 values for each tract the mean of which is taken to be the resource value of the tract. The ROV program is run by GS-New Orleans (NO), and they are responsible for the inputs and values assigned the parameters. The Bureau of Land Management directs GS-NO to use certain values for the price of oil, gas, and discount rate.

After GS-NO has evaluated the tracts and the ROV is complete, a pre-sale evaluating team composed of staff members from BLM-WO and BLM-NO reviews and audits the Geological Survey's product. This function is commonly done one week before a lease sale.

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c. Selection of Bidding System

In choosing a bidding system for OCS sales, the Department of the Interior considers the six following broad categories of objectives:

(1) timing of resource discovery
(2) timing of resource production
(3) efficiency of recovery
(4) environmental protection
(5) competitive structure of the oil and gas industry
(6) government revenues, i.e., receipt of fair market value

All of these factors are weighed carefully, though changing national priorities often shift the emphasis placed on these various objectives. However, even when national priorities and the corresponding objectives are clearly identified, picking the bidding scheme which most closely conforms to those objectives is often a difficult task. There are two explanations for this difficulty. Very little is known about decision-making behavior under uncertainty, especially for the risk-averse firm. Since the OCS is an environment of extreme uncertainty and since the firms competing for OCS leases are risk averse, the need for additional research in this theoretical area seems clearly established. A second problem that arises in selecting the most appropriate bidding scheme involves the trade-off among objectives. Frequently, government decision-makers must confront questions like: How much of a sacrifice in terms of receipt of fair market value are we willing to make in order to achieve improvements in efficiency of resource recovery? The dilemmas presented by questions such as these are not easily resolved.

Selecting the most appropriate bidding scheme is and will continue to be a formidable task. However, increasing interest in the difficulties of OCS development should hasten the advent of the expertise needed to resolve these problems.

In the OCS sale to be held in September, 1974, 10 tracts are being offered for sale on the basis of competitive royalty bids with a fixed cash bonus. Provisions for royalty reductions after production has been on stream for a minimum of one year have been included in the sale regulations. The outcome of this innovative sale is expected to have a significant impact on future OCS leasing policy.

d. Lease Sale

After tracts have been selected for a given proposed sale, a draft impact statement prepared and disseminated for review and comment, public hearings held, and a final impact statement prepared and disseminated, leases are let on the basis of competitive bidding. After the final statement is released, a sale notice is published in the Federal Register. The sale must be held at least 30 days after the sale notice. Sales are conducted by sealed bid,and the Secretary has the discretion of conducting the sale on a cash bonus, fixed royalty (not less than 12½%) basis, or on a royalty, fixed bonus basis. All OCS lease sales to date have been conducted on a cash bonus, fixed royalty (16 2/3%) basis, although an imminent sale (Louisiana #36) includes 10 tracts being offered on a royalty basis as a test of that system.

At a lease sale, which is open to all those desiring to attend, the tracts are treated sequentially using the tract numbering scheme for that sale. All the bids on a given tract are opened, the company(ies) biding is (are) identified aloud, and the amount of the total bid and the per acre figures are read aloud. No subjective judgments are made (e.g. indicating the high bidder); the certified checks or bank drafts accompanying the bids and the bids themselves are recorded. The amount of the check or draft is required to be one-fifth (20%) of the cash bonus bid. Running totals are kept of the dollar amounts bid and the dollar amount of apparent high bidders. No decisions or awarding of leases is done at this time.

e. Post-Sale Evaluation

Post-sale evaluation is conducted to determine the highest responsible qualified bidder for each tract, and to ensure that the Federal Government receives fair market value for each tract bid upon. A matrix is constructed for each tract which depicts several categories of information about the tract. Three values entered in the matrix are of most importance. The first is the mean of the range of values (ROV), which is the USGS presale estimate of the value of the tract. A second value is the mean of the ROV discounted 10% per year for two years. This is entered because a tract for which a high bid is rejected may not be re-offered for lease until final disposition of any appeal that may be filed. In the past, these appeals have required a minimum of two years to process, and thus the mean value is discounted to reflect the present value loss to the Government.

A third value for consideration is the average evaluation of the tract. This is calculated by summing all bids on the tract plus the Government's presale value and dividing by the total number of bids plus one. The significance of the average value increases with an increased number of bids on a given tract.

These values together with an analysis of the sale competition are used by the OCS Manager in deciding whether or not to accept a bid. The major components for analysis of sale competition are: average number of bids per tract by type of tract, the bidding performance of the high bidder by quarters, the average number of bids on tracts on which the high bidder bid, and per acre bids on adjoining and nearby tracts.

Types of tracts are divided into drainage, development, and wildcat tracts. The three types of tracts are separated in determining averages because drainage tracts (those whose reservoir(s) are being drained by production of an adjacent tract) typically receive fewer bids than the other two types; this might distort the average if all tracts were considered together.

The bidding performance of high bidder by quarters shows how many times the high bidder on the tract in question bid at the sale, and where this bid ranked in relation to other bids on tracts of interest. The average number of bids on tracts on which high bidder bid shows the level of competitive interest for tracts bid on by all high bidders. These two values are used to evaluate bidding strategy.

There are other components of the post sale matrix which allow some determination of environmental impact and orderly resource development. However, environmental considerations are made in earlier phases of each OCS leasing action. Tract reserves, leasing history of the tract, and status of production in the area are considered for the orderly and timely resource development.

2. Proposed Supervisory Procedures for OCS Resource Development

a. OCS Operating Regulations

Regulations governing OCS oil and gas lease operations in the Gulf of Mexico are contained in Title 30, Code of Federal Regulations (See Attachment A). These regulations will be applied probably with no change, to other geographic areas. Leasing regulations are contained in Title 43, Code of Federal Regulations (See Attachment A). The regulations established procedures and requirements to be followed in all stages of lease operations: exploration and development, drilling, production, transportation (pipeline construction and operation) and abandonment.

A general description of operating requirements under the existing regulations follows:

a. Plans: Operating plans must be submitted by the operators and approved by the U.S. Geological Survey (USGS) before each stage of operations is initiated (exploration, development, abandonment). Approval of all operations must be obtained prior to their commencement.

b. Operator Inspection and Testing: The operator is required to inspect all aspects of the safety systems at specific intervals, e.g., daily pollution inspection on manned facilities, "frequent" inspection on unmanned facilities, monthly test of check valves. Detailed records of inspections and tests are required.

c. Reports: The operator is required to report all spills or leakage of oil to USGS without delay. He is also required to notify USGS of any unusual condition, problem or malfunction within 24 hours (30 CFR 250.45)

d. Safety Devices: Required safety devices include subsurface safety devices, high-low pressure shut-in controls, high liquid level shut-in controls, pressure relief valves, automatic fail-close valves at the well head, automatic fire fighting systems, automatic gas detector and alarm systems, and other safety devices on production equipment; high-low pressure sensing devices and automatic shut-in valves on pipelines; and blowout preventers, related well control equipment, and mud system monitoring equipment on drilling wells.

e. Waste Disposal: The lessee is prohibited from disposing into the ocean any oil (except that oil in produced formation water must average no more than 50 ppm) (OCS Operating Order No. 8, Attachment B), untreated waste material or other materials which may be harmful to aquatic life or wildlife. Any drilling mud which may contain toxic substances must be neutralized before it can be dispersed in the ocean. (Waste disposals must comply with the 1972 Amendments of the Federal Water Pollution Control Act. Permits for disposals must be obtained from EPA under the National Pollutant Discharge Elimination System.) Sewage samples shall be collected semi-annually by lessee personnel and the samples submitted to a laboratory for analysis. Results of the analysis will be available on the platforms and rigs for inspection by the USGS technicians. USGS personnel are responsible for enforcing the requirement but do not take the samples.

f. Site Clearance: When an installation is no longer needed for development of the lease, the well is plugged with cement and all casings and piling must be severed and removed to at least 15 feet below the ocean floor and the location must be dragged to clear the site of any obstruction.

g. Debris: Regulations and OCS Orders prohibit the disposal of debris into the Gulf of Mexico. Solid waste must be either incinerated or transported to shore for disposal in accordance with applicable requirements under State and Federal law.

h. Contingency Plans and Equipment: The operator is required to have an approved plan for controlling and removing pollution which provides for:

(1) Standby pollution control equipment, including containment booms, skimming apparatus, and approved chemical dispersants immediately available to the operator at a land-based location.

(2) Regular inspection and maintenance of such equipment.

b. OCS Orders

OCS Orders derive their authority from 30 CFR 250 and carry the weight of the original OCS regulationd. They are issued by the USGS and are, in general, more specific, technical requirements than the regulations, and are designed to specifically define the responsibilities of offshore operators and methods of operating. At the present time, operating orders have been developed and are in use only for the Gulf of Mexico and Pacific (Calif.) OCS areas. Draft operating orders for Alaskan operations have been developed and are currently being reviewed by industry. The Department of the Interior will not hold lease sales in frontier areas until Operating Orders are developed for those areas.

The current Operating Orders address several different aspects of operations, have been developed over several years (1969-1972), and are currently undergoing review within USGS for possible amendments. (OCS Order No. 8 is being studied for possible amendment to prohibit concurrent production and workover on the same platform.) Gulf of Mexico Orders are found in Attachment B; several of these are identical for the Pacific, but the orders unique to the Pacific are also found in Attachment B.

c. Inspection Programs - Approval Requirements

Evidence of compliance with the regulations, orders, and other lease requirements is obtained through surveillance of the operations under the lease and enforcement of specific requirements. The inspection system of the Geological Survey includes: (1) review and approval of plans before each operating stage is initiated, (2) review and follow-up as necessary, by USGS inspectors, of all reports required of the operator by the regulations and orders, (3) on-site inspection and (4) aerial monitoring through the use of helicopters (operators are also required to inform each other of oil spills or other irregularities which they observe).

a. Operator reports: A comprehensive reporting system covering all oil spills and any unusual conditions (for example: reporting and investigation of a persistent oil slick from an unknown source such as a sunken ship or natural oil seep) is required by the orders and is a key factor in monitoring operations. Operators are also required to maintain records for USGS inspection of required periodic tests of safety equipment. Compliance with reporting requirements can be assured only by periodic on-the-site inspection and aerial monitoring.

b. On-Site Inspection: During the course of drilling, all operations are inspected at least one time. Leases in certain areas of the Gulf of Mexico or in a particular development stage may require more inspections to assure the achievement of safety objectives. USGS is continuing the systematic inspection program and a more stringent enforcement policy. This has resulted in increased operator compliance along with greater coverage of production operations and better documentation of inspection results.

A complete drilling inspection is normally conducted on each drilling rig approximately every six weeks. Random inspections may be made more frequently. Depending on the number of drilling rigs in each District, the frequency of inspections on a rig may vary from six to twelve per year. All producing platforms are inspected at least once a year and random inspections are made more frequently on some. The frequency rate for platform inspections is approximately once every nine months.

Listed below are the results of on-site inspections performed in response to the observations made during pollution surveillance flights conducted from December 1, 1972 through January 31, 1974:

Pollution Inspections	No. Platforms	No. Wells	Warnings	Suspensions
49	144	962	31	20

A program of intensive inspections is used on OCS leases. Periodically, all available inspectors devote a week to a special inspection, whereupon production platforms and drilling wells are inspected on a random basis; inspections during other periods are conducted on a regular basis with emphasis on operations believed to require special attention. The USGS inspector force in the Gulf of Mexico has increased from 7 technicians

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and 5 engineers as of July 1, 1969 to 28 technicians and 15 engineers as of January 31, 1974. During the period November 1, 1972 through January 31, 1974, technicians spent 4,188 inspection days or 34,893 man-hours, and engineers 452 inspection days or 3,614 man-hours in the field. Detailed inspections were conducted on 1,235 major producing platforms and 801 minor platforms (out of a total of 2000) in the Gulf of Mexico from December 1, 1972 through September 30, 1973. Also, during this time period, 813 inspections of single-wells or satellites were made by boat. Approximately 60% of these inspections were unannounced. Included in these inspections were 13,821 well completions. Also, during this time period, 1,311 inspections of drilling rigs were conducted. As of January 31, 1974 in a total of 11,383 holes, there were 9,691 completions capable of producing oil and gas on the OCS lands offshore Louisiana and Texas, not including service completions. Approximately 65 drilling rigs were operating in Gulf of Mexico OCS waters at the end of January, 1974.

c. Aerial Monitoring: "Fly-overs" of the OCS operating areas are programmed on a nearly daily basis by USGS inspectors. Any indications of oil pollution or other non-compliance is followed immediately by an on-site inspection.

During the period January 1 through September 30, 1973, 1,106 pollution surveillance flights were made. The helicopters chartered by the Geological Survey for use of the inspecting personnel flew a total of 4,088 hours.

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d. Enforcement

The enforcement policy is intended to: (1) reduce the frequency of non-compliance with lease requirements which may lead to loss of life, loss of property, or damage to the environment; and (2) maintain uniform enforcement standards to be applied to all operations affecting OCS lands in the Gulf of Mexico. When, in the course of an inspection, a requirement pertaining to the prevention of oil pollution or any other safety hazard is found to be in non-compliance, the operation will be shut-in until it is brought into compliance. After a shut-in, the operation can only be assumed by authorization of the USGS; in all cases, this requires reinspection or a waiver of the inspection requirement. Minor incidents of non-compliance may require only a warning that corrections be made within a week. The operations will be shut-in if the required corrections are not made.

Additional penalties for non-compliance are specific in P.L. 83-212, Outer Continental Shelf Lands Act, Sec. 5(a)(2). "Any person who knowingly and willfully violates any rule or regulation prescribed by the Secretary for the prevention of waste, the conservation of the natural resources, or the protection of correlative rights shall be deemed guilty of a misdemeanor and punishable by a fine of not more than $2,000 or by imprisonment, and each day of violation shall be deemed to be a separate offense." Also Sec. 5(b)(1) and (2) provide for cancellation of non-producing and producing leases by notice subject to judicial review or appropriate judicial proceedings.

The following tables (Tables 3-5) indicate equipment malfunctions detected during inspections and enforcement actions over three separate periods. Minor incidents of non-compliance result in formal warnings while incidents of non-compliance of a potentially more hazardous nature result in well or platform shut-ins until the operation is in full compliance with regulations and orders.

These tables indicate specific items found to be in non-compliance during special inspections. Basic pollution control items of production equipment in which malfunctions were detected for the time periods identified are as follows:

Table EQUIPMENT MALFUNCTION DETECTED DURING JANUARY THROUGH NOVEMBER, 1971 SPECIAL INSPECTIONS

	No. Checked	Operable	Inoperable or not within acceptable tolerance	Percent Failure
Surface Safety valves	2392	2306	86	3.6%
Flowline sensors	4166	4081	85	2.0%
Check Valves	2222	2052	170	7.7%
Pressure vessels				
High pressure sensors	908	875	33	3.6%
Low pressure sensors	765	744	21	2.8%
Low level shut-in	511	481	30	5.9%
High level shut-in	460	439	21	4.6%
Total	11,424	10,978	446	3.9%

Table 4. EQUIPMENT MALFUNCTION DETECTED DURING JANUARY THROUGH NOVEMBER, 1972 SPECIAL INSPECTION

	No. Checked	Operable	Inoperable or not within acceptable tolerances	Percent Failure
Surface Safety Valves	1,492	1,423	69	4.6%
Flowline sensors	1,327	1,290	37	2.8%
Check Valves	1,469	1,385	84	5.7%
Pressure Vessels				
High pressure sensors	1,100	1,077	23	2.1%
Low pressure sensors	784	771	13	1.7%
High level shut-in	405	398	7	1.7%
Low level shut-in	383	375	8	2.1%
Total	6,960	6,719	241	3.5%

Table 5. EQUIPMENT MALFUNCTIONS DETECTED JANUARY THROUGH SEPTEMBER, 1973 SPECIAL INSPECTIONS

	No. Checked	Operable	Inoperable or not within acceptable tolerances	Percent Failure
Surface safety valves	1,188	1,131	57	4.8%
Flowline sensors	385	378	7	1.8%
Check Valves	1,170	1,092	78	6.7%
Pressure Vessels				
High pressure sensors	857	841	16	1.8%
Low pressure sensors	521	514	7	1.3%
High level shut-in	217	212	5	2.2%
Low level shut-in	258	251	7	2.7%
Total	4,596	4,419	177	3.9%

It can be seen that over the 3-year period, detected malfunctions (as percent failure) have declined slightly in most categories, but not enough to state that more advanced technology or greater compliance is significantly reducing the risk of spills in the offshore environment.

Surface operated subsurface safety valves are periodically pulled from the wells and checked. This requires removing the valve from the well to inspect and repair or adjust as necessary and reinstall. One company utilized test stands to test the valves performance characteristics under simulated flow and pressure conditions. Surface operated subsurface safety valves are tested in place by releasing hydraulic pressure within the closed system to close the valve and repressuring to open. An average reporting period from May 1973 through July 1973 resulted in approximately 3,000 subsurface safety valves being checked. Of this amount there were 394 failed components detected in the valves but a number of the valves had more than one failed component.

Companies fined in District Court for failure to install subsurface safety devices in offshore oil wells during 1970 in the Gulf of Mexico are presented below. Each company entered a plea of nolo contendere. The maximum fine for violation of the Outer Continental Shelf Lands Act is $2,000 per count, each day being a separate count.

MAXIMUM FINES

Chevron Oil Company	$1,000,000
Gulf Oil Company	250,000
Tenneco	32,000
Kerr-McGee	20,000
Mobil	150,000
Continental	242,000
Humble	300,000
Shell	340,000
Union of California	24,000
	$2,358,000

The total number of warnings and suspensions ordered for infractions of OCS Orders which occurred during normal inspections from December 1, 1972 through January 31, 1974, are as follows:

WARNINGS			SUSPENSIONS		
Drilling	Workover	Production	Drilling	Workover	Production
35	3	2,164	15	4	1,198

No date for direct comparision of pollution incidences for similar time periods before and after the current "more stringent enforcement policy" are available. This "policy" is difficult to reconsile with the decline in the number of inspections made on different pieces of equipment from 1971 to 1973 (See Tables 3 , 4 , 5). However, experienced personnel, private and government, are aware that after public attention was focused on the oil spill at Santa Barbara in January 1969, there has been a great deal less oil pollution in the Gulf from normal oil and gas producing operations. The public awareness, concern, and demand to prevent pollution have been a major factor in the reduction of oil spills.

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In the past, major events were catalogued, but less serious events were often not reported. Occasionally, some years ago, wells were even intentionally flowed into the water for short periods during cleanup operations. Now, burning devices are designed to consume this well clean-up oil without air or water pollution. More automatic equipment is now in use to shut-in production whenever a leak occurs in pipeline or production facilities. These include, but are not limited to, pressure sensors and high and low level controls. Drip pans are placed under valves, vessels, and the production system to prevent leaking oil from escaping into the waters of the Gulf.

New reporting and investigative procedures established in the last two years have increased many fold the number of pollution incidents reported as well as the time spent by USGS personnel in surveillance flights by helicopters in assuring proper documentation of pollution events.

There have been several detailed studies recently completed concerning operating practices on the OCS. The Department's response to these studies and the steps being taken at this time will improve many facets of OCS management practices. These studies are discussed in a later section of this statement.

e. Contingency Plans for Oil Spills

Oil spills will occasionally occur as a result of natural disasters, equipment failure or human error. In the event that such an emergency occurs, the following actions will be taken:

(1) Requirements of OCS Order No. 7 1/

In the case of any spill, the operator is required to initiate action to control or remove the oil pollution in accordance with his approved emergency plan. In any case, a spill or leakage of less than 15 bbls. requires a report from the operator as to the nature of the spill or leakage, why it occurred and what steps were taken to correct it. A spill of 15-50 bbls. must be reported by telephone immediately to USGS and confirmed in writing. A spill of over 50 bbls, or one of any magnitude that cannot be immediately controlled, must be reported immediately to the Coast Guard and the Environmental Protection Agency as well as to USGS.

(2) Regional or National Contingency Plans

If the operator should be unable to control and remove the pollution, the Regional or National Oil and Hazardous Substances Pollution Contingency Plan may be activated and the designated Federal On-Scene Coordinator would direct control and

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1/ See Attachment B.

clean-up operations at the operator's expense. This has never been necessary in the case of any spill since the inception of the Plan in 1973.

The Regional or National Oil and Hazardous Substances Pollution Contingency Plan was developed pursuant to the provisions of the Federal Water Pollution Control Act as amended (33 U.S.C. 1101). (EPA has published the revised National Oil and Hazardous Substance Pollution Contingency Plan as requird by the Federal Water Pollution Control Act Amendments of 1972.) Section 11(c)(2) of that statute authorizes the President, within sixty days after the sections becomes effective, to prepare and publish such a Plan. The Plan provides for efficient, coordinated, and effective action to minimize damage from oil (and other) discharges, including containment, dispersal, and removal. The Plan includes (a) assignment of duties and responsibilities, (b) identification, procurement, maintenance and storage of equipment and supplies, (c) establishment of a strike force and emergency task forces, (d) a system of surveillance and notice, (e) establishment of a national center to coordinate response operations, (f) procedures and techniques to be employed in identifying, containing, dispersing and removing oil, and (g) a schedule identifying dispersants and other chemicals that may be used in carrying out the Plan, the waters in which they may be used, and quantities which may be safely used. Annex X of the Plan basically sets forth a no dispersant policy. Exceptions can be made for safety reasons (to prevent fire or explosions) or for certain other circumstances such as the protection of endangered waterfowl. However, the approval of EPA is required, except in case of safety when the approval of the On-Scene Coordinator is required. The Plan will be revised from time to time as necessary. Operation of the National Contingency Plan requires a nationwide net of regional contingency plans. Guidelines for that nationwide net are established in the National Plan. This plan provides for a pattern of coordinated and integrated responses to polluting spills by departments and agencies of the Federal Government. It establishes a national response team and provides guidelines for the establishment of regional contingency plans and response teams. The Plan also promotes the coordination and direction of Federal, State, and local response systems and encourages the development of local government and private capabilities to handle such pollution spills.

The Plan is effective for all United States navigable waters including inland rivers, Great Lakes, coastal territorial waters, and the contiguous zone and high seas beyond this zone where a threat exists to United States waters, shoreface, or shelf-bottom. Its provisions are applicable to all Federal agencies. The Plan is presently operative in the Gulf of Mexico only.

A memorandum of understanding between the Departments of the Interior and Transportation outlines the respective responsibilities of the Geological Survey and the Coast Guard under the National Contingency

Plan. USGS is responsible for the coordination and direction of measures to abate the source of pollution when the source is an oil, gas, of sulphur well. This responsibility includes the authority to determine whether pollution control operations within a 500 meter radius of the pollution source should be suspended to facilitate measures to abate the source of pollution. The Coast Guard is responsible for coordination and direction of measures to contain and remove pollutants, and shall furnish or provide for the On-Scene Coordinator authority and responsibilities as provided by the National Contingency Plan.

(3) Petroleum Industry Contingency Actions

(a) Inventory of Known Resources Available for Emergency Oil Spill Control and Clean-up

From the upper Texas Coast to the Mississippi Delta region offshore operators maintain a large inventory of various kinds of equipment that could be put to use on short notice for containing and cleaning up an oil spill and killing the source of the spill. This inventory includes 177 boats ranging from 30 foot crewboats to 165 foot utility and cargo vessels, 64 helicopters, 103 fixed-wing aircraft.

(b) Clean Gulf Associates

Clean Gulf Associates is a non-profit organization formed by thirty-three companies operating on the OCS in the Gulf of Mexico. Their purpose is to provide for a stockpile of oil spill containment and clean-up materials for use by member companies in offshore and estuarine areas. Clean Gulf Associates has contracted, effective August 1, 1972, with Halliburton Services to supply equipment, materials and personnel necessary to contain and clean-up spills in the Gulf of Mexico to the limits of the OCS lying offshore and seaward of the States of Texas, Louisiana, Mississippi, Alabama, and Florida. Before any drilling commences in this area, an inventory of pollution combatting equipment would be stockpiled at a stragetic location. Should oil reservoirs be found and production ensue, a permanent base for containment and clean-up equipment will be established.

At the present time, Halliburton maintains four types of recover/clean-up systems for development at two primary bases located at Intercoastal City, and Grand Isle, Louisiana, and a sub-base at Venice, Louisiana and include:

(1) Fast response open sea/bay skimmer system

(2) High volume open sea skimmer system

(3) Shallow water skimmer system

(4) Auxiliary shallow water and beach clean-up equipment.

This type of organization could and should be established in any frontier area before exploration begins. Clean Seas is a similar group in California that can be geared up, should that area be re-opened for leasing. Federal approval must be given for all such clean-up groups.

f. Liability for Oil Spills

OCS Order No. 7 indicates quite clearly that the liability for oil spills rests entirely with the lessee.

> (b) If the waters of the sea are polluted by the drilling or production operations conducted by or on behalf of the lessee, and such pollution damages or threatens to damage aquatic life, wildlife, or public or private property, the control and total removal of the pollutant, wheresoever found, proximately resulting therefrom shall be at the expense of the lessee. Upon failure of the lessee to control and remove the pollutant the supervisor in cooperation with other appropriate agencies of the Federal, State and local governments, or in cooperation with the lessee, or both, shall have the right to accomplish the control and removal of the pollutant in accordance with any established contingency plan for combating oil spills or by other means at the cost of the lessee. Such action shall not relieve the lessee of any responsibility as provided herein.
>
> (c) The lessee's liability to third parties, other than for cleaning up the pollutant in accordance with subsection (b) above, shall be governed by applicable law.

g. OCS Regulations of Other Federal and State Agencies

Regulation and supervision of OCS oil and gas operations is not strictly a BLM-USGS responsibility, but rather a multi-agency network of responsibilities (sometimes overlapping) that attempts to give those agencies with particular expertise or historical responsibility in different facets of the marine environment control over those functions. These responsibilities are addressed below.

(1) Department of Transportation

(a) U. S. Coast Guard

The responsibilities of the Coast Guard are as follows: 1) insuring that structures on the OCS are properly marked to protect navigation (lights-number, arrangement, and power; identifying numbers on structure - size and location); 2) establishing and enforcing safety regulations on these structures; 3) maintaining surveillance during all cruises and overflights of the OCS for spilled or discharged oil; 4) inspecting and certifying all floating drilling rigs except those which rest on bottom during drilling.

(b) Office of Pipeline Safety (OPS)

The OPS has general responsibilities for pipelines. It primarily supervises gas pipeline safety, including the establishment of design criteria directed toward increased safety.

(2) Environmental Protection Agency (EPA)

The EPA has several functional responsibilities in the OCS leasing program. It is directly involved in the critical review of the draft environmental impact statement, for which it provides extensive, substantive comments. EPA also has a system whereby all draft impact statements are rated for adequacy, and it has recently instituted a policy of reviewing all final statements, but without rating them for adequacy.

The EPA is also required by Section 403 of the Federal Water Pollution Control Act (FWPCA) Amendments of 1972 to establish standards under which a permit for discharge of pollutants into navigable waters of the U. S. may be issued. While this responsibility has not yet been tested, and there is some controversy concerning the applicability of Amendments to the OCS beyond the contiguous zone, the EPA could eventually wield a high degree of control over operations on offshore structures.

The EPA, along with the departments of Interior, Transportation, and Defense, are designated the four primary Federal agencies responsible for the organization, management, design of response, and actual response to polluting incidents under the National Oil and Hazardous Substances Pollution Contingency Plan, which was incorporated into the FWPCA Amendments of 1972. The EPA is also a member of the OCS Research Management Advisory Board.

(3) Corps of Engineers, U.S. Department of the Army

The authority of the Secretary of the Army, which is delegated to the Corps of Engineers, ". . . to prevent obstruction to navigation in the navigable waters of the United States is hereby extended to artificial islands and fixed structures located on the Outer Continental Shelf," is derived from Section 4(f) of the OCS Lands Act. In general, since the Coast Guard regulates above water structures, Corps responsibility has been taken as permitting of structures and pipelines. The

Corps requires that pipelines crossing shipping fairways be buried to a depth of 10 feet.

(4) Federal Power Commission (FPC)

The FPC has discretionary powers over the approval, design and economics of common carrier gas pipelines. It also determines what the price of OCS gas will be at the wellhead. This regulated price is the base price from which the final price is determined, after costs and profit have been added. The FPC also is solicited for review and comment of draft impact statements on lease sales. The FPC issues the certificates of public convenience and necessity that are necessary for gas pipeline construction.

(5) Other Federal Agencies

(a) Fish and Wildlife Service (FWS)

The FWS (formerly the Bureau of Sport Fisheries and Wildlife) has a broad mandate to study, protect and manage fish and wildlife resources. In the offshore environment, these resources include sport fish, marine mammals, and marine birds. Onshore, FWS is concerned with fish and wildlife and the habitats where they abide, as well as numerous refuges under FWS jurisdiction. In the leasing program, FWS' primary role is as a reviewing agency for draft impact statements. FWS has also participated in the design of several OCS related study programs sponsored by BLM, and is a member of the OCS Research Management Advisory Board.

(b) Federal Energy Administration (FEA)

This newly created agency has broad discretionary powers over matters pertaining to energy supply and demand in the U. S. The FEA has been given the directive to implement and monitor the progress of Project Independence, among numerous other duties, and is making strides at understanding and monitoring the OCS leasing program. The FEA has recently been added to the list of agencies which are solicited for review and comment of OCS leasing impact statements.

(c) National Oceanic and Atmospheric Administration (NOAA)

The NOAA, in the Department of Commerce, has broad jurisdictional powers over many aspects of the marine environment. The number of projects and responsibilities are too numerous to list here. Historically, the prime involvement of NOAA in the OCS leasing program has been through the National Marine Fisheries Service (NMFS), which extensively reviews and comments on draft impact statements. The NMFS is concerned with all types of potential impacts on marine fish, especially commercial fisheries. The NOAA has a representative on the OCS Research Management Advisory Board, and is undertaking the environmental baseline studies being sponsored by BLM in the Gulf of Alaska.

(6) State Agencies - General Authorities

In general, the OCS Lands Act withdrew most control over OCS oil and gas production from coastal state jurisdiction. However, physical, chemical, geological, and biological provinces and habitats overlap Federal - State boundaries, and thus the coastal states have an interest in offshore activities that might affect their coastal resources. In addition, there are obvious economic benefits and disbenefits to a coastal state as a result of offshore development in the forms of construction equipment, refinery employment if refineries are in existence or proposed, and host of related services, secondary employments and income to the state.

There have been excellent working relationships for many years between the Federal Government and the states of Louisiana and Texas regarding offshore development. Various aspects of the program will necessitate interfacing of Federal and State governments, such as: continued review by States of proposals and environmental impact statements, relationship of OCS development to States' land use planning under the Coastal Zone Management Act of 1972, and joint participation in research projects such as pipeline corridor studies and baseline environmental inventories.

3. Related Management and Supervisory Authorities

a. Coastal Zone Management Act

The Coastal Zone Management Act of 1972 ([illegible] 93-583, 92nd Congress) established Federal policy by authorizing Federal assistance to States for developing programs of coastal zone land use control and providing for States approval of Federal projects in the coastal zone. This puts authority in States' control for any coastal zone development related to offshore oil and gas exploration and transportation. The Act is environmental in orientation and is aimed at balancing the protection of the coastal zone with economic interests. Several states have applied for funding to develop their land use plans, and the State of Marine at least has already received such funding.

b. Federal Water Pollution Control Act (1972 Amendments)

The provisions of this Act have been stated in the previous section on enforcement and contingency plans. In general, FWPCA as amended in 1972 gives the EPA broad discretionary powers in setting and enforcing standards and levels of water pollution (both fresh and marine water) from all sources. Section 311(b)(3) prohibits ". . . the discharge of oil or hazardous substances into or upon the navigable waters . . . adjoining shorelines, or into or upon the waters of the contiguous zone in harmful quantities." This section also provides for the National Contingency Plan mentioned previously. Under this authority, the EPA issued standards and measures for oil pollution prevention effective January 10, 1974 (_Federal Register_, December 11, 1973), proposed petroleum effluent limitation guidelines and new source standards (_Federal Register_, December 14, 1973), proposed designation of hazardous substances (_Federal Register_, August 22, 1974), and proposed regulations for water quality and pollutant source monitoring.

c. _Land and Water Conservation Fund Act_

The Land and Water Conservation Act of 1965 was signed into law by President Johnson on September 3, 1964. While this legislation is not related to management or supervision of OCS oil and gas, it is related to and dependent upon monies generated by lease sales and production royalties. It created outdoor recreation "accounts" for all 50 States, Puerto Rico, Virgin Islands, Guam, American Samoa, and the District of Columbia. More than $1 billion in Federal funds, derived primarily from offshore oil royalties, has gone to the 55 jurisdictions noted above, and $600 million has gone to the principal Federal land managing agencies -- Bureau of Land Management, National Park Service, Fish and Wildlife Service, and the Forest Service -- for the acquisition of lands authorized by Congress for Federal management.

The Fund was viewed as seed money for creation of recreation areas and facilities which the States, rather than the Federal Government, would manage. Other than overseeing compliance requirements, Federal officials have no role in the management of any of the State recreation areas acquired or developed with the billion dollars of Fund money.

The Bureau of Outdoor Recreation, designated by the Secretary of the Interior as manager of the Fund, makes about 2200 grants each year, ranging from a few thousand to several million dollars.

d. Endangered Species Conservation Act

The Endangered Species Conservation Act of 1969 (16 U.S.C. 688aa) requires the Secretary of the Interior to publish in the Federal Register and periodically to modify two lists of species or subspecies of vertebrates, mollusks, or crustaceans he has determined to be either threatened with extinction within the territory of the United States or threatened with worldwide extinction. The occurrence of endangered animals in areas, either onshore or offshore, which might be affected by OCS oil and gas development is noted in environmental impact statements on such development, and is an important consideration in the decision-making for OCS lease sales. In 1973, the Fish and Wildlife Service (then Bureau of Sport Fisheries and Wildlife) published Threatened Wildlife of the United States (vertebrates only), a source document for the determination of endangered species, which can only be designated in the *Federal Register*.

The responsibility for the management and protection of most wildlife in the U. S. lies with the various State Conservation agencies rather than the Federal Government. An animal receives no additional Federal protection as a result of having been placed on the "List of Endangered Native Fish and Wildlife."

On December 28, 1973, Congress passed the "Endangered Species Act of 1973." This Act calls for determination of endangered species on a worldwide (rather than just U.S.) basis, authorizes land acquisition for protection of endangered species, authorizes the Secretary of the Interior to enter into cooperative agreements with States, other Nations, and other agencies for the protection and management of said species, establishes prohibited acts and the penalties and enforcement procedures necessary for protection.

e. Proposed Land Use Policy and Planning Assistance

Prior to the enactment of the Coastal Zone Management Act in 1972, at least 15 coastal states had already passed some form of coastal management legislation. The following list (Zwicky and Clark, 1973) indicates these States and includes a reference to this legislation and its year of enactment.

California: Coastal Zone Conservation Act (Proposition 20: 1972)

Connecticut: Wetlands Protection Act (Act 695: 1969)

Deleware: Coastal Zone Act (Act 175: 1971); Wetlands Act (Sen. Bill 217: 1973)

Georgia: Coastal Marshlands Protection Act of 1970 (Act 1332: 1970)

Maine: Coastal Wetlands Act (Act 541: 1971); Mandatory Zoning and Subdivision Control (Chapter 535: 1971)

Maryland: Wetlands Act (Act 241: 1970)

Massachusetts: Coastal Wetlands Act (Act 768: 1965)

Mississippi: Coastal Wetlands Protection Act (House Bill 140: 1973)

New Hampshire: Dredge and Fill Act (Act 215: 1967)

New Jersey: Wetlands Act (Act 272: 1970); Coastal Area Facility Review Act (Assem. Bill No. 1429: 1973)

New York: Tidal Wetlands Act (Chapter 790: 1973)

North Carolina: Dredge and Fill Law/Coastal Wetlands Act (Act 1159: 1971)

Rhode Island: Coastal Wetlands Act (Act 140: 1965); Coastal Resources Management Council Act (Act 279: 1971)

Virginia: Wetlands Act (Chapter 711: 1972)

Washington: Shoreline Management Act (Act 286: 1971)

The three most common reasons for such legislation were: 1) to protect wildlife and fisheries; 2) to preserve and protect ecosystems, living resources, the natural environment, or lands; and 3) to control development or growth, regulate use of land and/or reduce the burden on municipal services (Zwicky and Clark, 1973)

With the passage of the Coastal Zone Management Act in 1972, the Federal Government made a major step toward aiding coastal states in the development of cogent land use planning for the coastal zone. Funds were made available to applicant States for the drafting of land use plans, or for further definition and implementation of acceptable existing land use legislation. Numerous states have applied for such funding. The lead agency for carrying out the provisions of CZMA is the Department of Commerce, through NOAA's Office of Coastal Environment. Other agencies are also involved with this program. Land use policy is also involved in several specific projects requiring cooperative efforts between States and the Federal Government, such as proposed pipeline corridor studies conducted by affected States and BLM-USGS.

4. OCS Research Management Advisory Board

On March 20, 1974, the Secretary of the Interior established the Outer Continental Shelf Research Management Advisory Board under the provisions of the Federal Advisory Committee Act. The objective of the Board is to advise the Assistant Secretary - Land and Water Resources, the Director of the Bureau of Land Management, and other offices of the Department, in the design and implementation of environmental research projects related to oil and gas exploration and development on the OCS. The formally instituted Board is an outgrowth of an interagency ad hoc committee that began meeting in January, 1974 for the purpose of designing the baseline study to be conducted on the Mississippi, Alabama, Florida (MAFLA) OCS.

As the scope of future baseline and monitoring studies was expanded and a commitment of funds were made to the Department from the Office of Management and Budget, the need for a chartered Board became apparent. The establishment, functions, and charter of the Board are attached to this statement as Appendix .

In general, the charter calls for the Assistant Secretary - Land and Water Resources to appoint a Department of Interior employee as chairman of the Board, after consulting with the Assistant Secretary - Energy and Minerals, and the Assistant Secretary - Fish, Wildlife, and Parks.

Each of the following Government agencies shall appoint one member: Geological Survey, Fish and Wildlife Service, Environmental Protection Agency, and National Oceanic and Atmospheric Administration. In addition, provisions are made for one member to join the Board from each coastal State which has such environmental studies planned for the OCS off that State. An annual report of the status of ongoing research shall be provided to the Secretary. A Chief Scientist for this program from BLM will attend all Board meetings, or send a representative.

It is intended that the members of the Board be scientists, or administrators who are familiar with ocean research and the design of large-scale environmental studies. These studies, primarily the monitoring aspect, are expected to continue for approximately ten years. Funding for the remainder of FY 74 was $1.3 million (primarily MAFLA baseline work), and the budget request for FY 75 was $9.7 million. Most of this request, when approved, will be devoted to baseline work in the Gulf of Alaska and South Texas.

5. Environmental Data Gathering Programs

a. Inventories and Analyses of Existing Environmental and Socio-Economic Data

The following discussion is a compilation of studies, completed, in progress, and planned, designed to acquire existing environmental and socio-economic data that relate directly or indirectly

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to the exploration, development, production, transportation, and refining of OCS derived oil and gas. These studies have been or will be funded by various sources, and will complement the newly acquired baseline and monitoring information to allow analyses of the impacts of the OCS oil and gas leasing program.

(1) CEQ Report

The Council on Environmental Quality was directed by the President in April, 1973 to conduct an environmental impact assessment of oil and gas production on the continental shelves of the Atlantic coasts and the Gulf of Alaska. The CEQ report was released in April, 1974 after several public hearings were held, results of contract studies were available, and a critique of the draft report was performed by the National Academy of Sciences.

The CEQ report, OCS Oil and Gas - An Environmental Assessment, addresses the following topics in detail: oil and gas resources, energy growth (demand and supply), resource development technologies and an assessment of them, offshore and onshore effects of development, and management mechanisms for OCS development. The summary of findings ranks several prospective areas on the basis of hydrocarbon potential and environmental considerations. The highest environmental risk of development was assigned to the Northern Baltimore Canyon, Southeast Georgia Embayment, and Gulf of Alaska. These risks were based mainly on probabilities of oil spills reaching shore in these areas; these probabilities were determined using an oil spill trajectory model developed for CEQ by the Massachusetts Institute of Technology.

The conclusion of the CEQ report is that OCS development could be conducted in the Atlantic and Gulf of Alaska, but only if CEQ recommendations and stipulations are accepted. One point was clear. There are large gaps in the scientific information that cause problems in analyzing and predicting the impacts of OCS oil and gas development. Environmental baseline and monitoring studies appear necessary in these areas; the baseline aspect should be begun as soon as possible in these (and other) frontier areas.

(2) Department of Interior Contracts

As an integral part of its OCS leasing program, the Bureau of Land Management has undertaken a broad-based inhouse and outside contract study effort to aid in the design, modification, and implementation of the leasing program. Besides the large-scale baseline and monitoring studies discussed later, the Bureau has awarded several contract studies for the purpose of gathering and consolidating available environmental and socio-economic data in several geographic areas. The topics of primary interest in environmental studies are: (1) coastal zone--climate, ecology, physical properties, man-made features, and hydrography, and (2) continental shelf--physical oceanography, meteorology, geology and marine ecology.

The socio-economic studies will review industrial and commercial activity, petroleum industry development, demography, land and water use, sources of pollution, and existing transportation systems.

(a) Atlantic Area

The Bureau of Land Management is presently funding the study, A Socio-Economic and Environmental Inventory of the North Atlantic Region. This study is being conducted by the Research Institute of the Gulf of Maine (TRIGOM). The draft report constitutes a substantial effort to collect and summarize all available environmental and socio-economic information (no original research) pertaining to the Atlantic coastline from Sandy Hook, New Jersey, to the Bay of Fundy. This report is expected to be completed by March, 1975.

A contract for the gathering of socio-economic data pertaining to mineral leasing on the OCS from Sandy Hook, New Jersey to Cape Hatteras, North Carolina, has been awarded to the College of Marine Studies, University of Delaware.

The CEQ, through a transfer of funds from BLM, has issued a contract to study to evaluate environmental and socio-economic conditions from Cape Hatteras to Cape Canaveral, Florida. This study is nearing completion, is similar to the TRIGOM study above, and is being conducted by the Virginia Institute of Marine Science.

The Bureau of Land Management is presently funding a long-term study of the fate and effects of No. 6 oil (a heavy fuel oil) in a high temperate estuary (Casco Bay, Marine). This research effort is being conducted by the Bureau of Marine Resources of the State of Maine. Investigations include weathering, oil residence time in sediments, biological concentrations within the clam _Mya arenaria_, and the chronic effects of oiling on _Mya_.

This effort is part of a three year continuation of a major (100 - 570,000 gallons) spill in an area which had not been significantly oiled before or after this. Studies include gas chromatographic analyses of oil residues in sediment and in the clams, and the general ability of oiled clams to grow and function.

This study is relatively unique in its rapid initiation after the spill, and its uninterrupted investigations to date.

Preliminary data indicate mass mortalities in heavily oiled clam beds initially, and slow recruitment in these beds in the first three years. Clams in initially oiled beds have remained inedible causing considerable economic loss to the local fish industry.

(b) Gulf of Mexico

A study of the Gulf of Mexico was awarded to Environmental Consultants of Dallas, Texas. The contract calls for an updating and broadening of the Cooperative Investigation of the Caribbean and Adjacent Regions (CICAR) Bibliography that was published in 1972 by the U.S. Department of Commerce's National Oceanic and Atmospheric Administration. The contract also provides for identification of research in progress relating to CICAR categories and a socio-economic study of the Gulf of Mexico. A contract was recently issued by BLM to TerEco Corporation of College Station, Texas entitled "Ecological Aspects of the Upper Continental Slope, Gulf of Mexico". The study is an analysis of organisms and sediments that have already been collected from the continental slope from DeSoto Canyon off Louisiana to the Mexico-U.S. border. Organisms will be identified, population sizes and distributions determined, and correlations of organism occurrences will be made with sediment type analyses, temperature-salinity characteristics, and depth. This study is scheduled for completion in June, 1975.

An investigative effort has been proposed to conduct a submersible reconnaissance of 14 to 18 topographic highs on the Texas OCS. The reconnaissance would allow visual (operators' reports, videotape, still photographs) characterization of these sites as potentially

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valuable resources (commercial fish havens, reefs or reef-type communities). Biological and geological sampling will also be conducted. It is not known at this time whether this effort will be conducted separately from, or in conjunction with, the environmental baseline studies in the South Texas area.

The baseline studies in the South Texas area, as well as their forerunner in the eastern Gulf (MAFLA) area, are discussed in a later section.

An inhouse study in cooperation with the States of Mississippi, Alabama, and Florida has been initiated to conduct a pipeline corridor analysis of the northeastern Gulf of Mexico. This study will analyze for suitable physical, geological and onshore developmental areas for corridors.

(c) Southern California

The study of the Southern California offshore borderland area was awarded to the Southern California Ocean Studies Consortium (SCOSC). This study, which is nearing completion, will include existing environmental and socio-economic aspects of mineral leasing in this area.

In addition, a contract for the development of an oil transportation computer model was awarded to Stanford Research Institute of Menlo Park, California. This model will aid in the analysis of Outer

Continental Shelf oil resources and alternative sources of petroleum supply to help meet future regional demands and to assess the effects of prices and transportation costs relating to regional supplies and flow patterns.

(d) Alaska

The Gulf of Alaska and adjoining OCS areas of the Pacific Ocean, Cook Inlet to Unimak Island - was awarded to The Arctic Environmental and Data Center of the University of Alaska at Anchorage, Alaska. The study will include environmental and socio-economic data.

Baseline environmental data collection is already planned for the Gulf of Alaska, the data collection to be conducted by NOAA.

(3) Other Applicable Studies

There have been several studies recently completed which identify weaknesses in OCS operating regulations and procedures and recommend remedial measures. The Geological Survey had undertaken on their behalf studies conducted by NASA 1/, the Marine Board of the National Academy of Engineering 2/, and an internal System Laboratory

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1/ NASA, "Applicability of NASA Contract Quality Management and Failure Mode Effect Analysis Procedures to the USGS Outer Continental Shelf Oil and Gas Lease Management Program", November, 1971.

2/ Marine Board, National Academy of Engineering, "Outer Continental Shelf Resource Development Safety: A Review of Technology and Regulation for the Systematic Minimization of Environmental Intrusion from Petroleum Products", December, 1972.

Group of the Water Resources Division of the Geological Survey [1]. An analysis of the results of these studies was completed by a special Work Group of the GS in May, 1973, and a report titled the "Work Group on OCS Safety and Pollution Control" was issued. Implementation has commenced on all 15 recommendations made by the Work Group in its report.

In addition to the above studies and reports, the General Accounting Office (1973) issued a report at the request of the Conservation and Natural Resources Subcommittee of the Committee on Government Operations, House of Representatives. This study, like those mentioned above, presents a critical review of OCS regulatory and inspection procedures and includes recommendations designed to achieve more effective capability and procedures. In a letter dated August 3, 1973, from Secretary Morton to Mr. Henry S. Reuss, Chairman of the Conservation and Natural Resources Subcommittee, it is pointed out that the recommendations contained in the GAO report which have not already been implemented are being implemented as part of the Work Group's recommendations. Many of the recommendations contained in the GAO report were also made in the studies discussed above.

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[1] USGS, "Outer Continental Shelf Lease Management Study", May, 1972.

A comprehensive report of a technology assessment of oil and gas operations on the U.S. Outer Continental Shelf was published by an interdisciplinary research team from the Science and Public Policy Program at the University of Oklahoma (Kash, *et al.*, 1973). The independent analysis, funded by the National Science Foundation, was conducted over a 20 month period beginning in September, 1971.

The principle conclusions of the study are: (1) That existing OCS technologies are adequate for continued oil and gas operations; (2) that more sharply defined concerns for safety and environmental protection continue to pose a challenge to OCS management even though technologies responsive to these new concerns are gradually evolving; (3) that in the past, participation in the management of OCS oil and gas operations was limited to the Department of the Interior and the petroleum industry and that this relatively closed management system was initially unable to sense and respond quickly to a changing social climate. Interested groups and Federal agencies representing concerns such as environmental conservation are now participating in the management system primarily through the impact statement process required by NEPA. These new participants are demanding changes from past patterns of operations; and (4) most of the new demands being made on OCS technologies are well within state-of-the-art. The necessary information modifications in the physical technologies required by a changing social climate can be met. Although the application of stringent environmental and safety criteria pose problems, the industry either has or can develop the required physical technologies and procedures. The Work Group of the GS in May 1974 issued 'Supplement No. 1 to the Report of the Work Group on OCS Safety and Pollution Control, May 1973.'

> "This report considers the recommendations of the Oklahoma University study which were directed to the Geological Survey as a result offers revision to previous recommendation nos. 4, 9, and 13, and adds four additional recommendations. The Director of the Geological Survey has accepted these recommendations and implementation has commenced."

The American Petroleum Institute funded a study conducted by the University of Rhode Island which was published in 1974. This study attempted to review all significant literature pertaining to environmental and socio-economic conditions along the Atlantic coastline from Cape Hatteras to Sandy Hook, New Jersey.

b. Potential Special Field Studies

Studies involving field or laboratory research, as opposed to existing information searches, which have been proposed but not yet fully funded or developed include the following:

1. A submersible reconnaissance mission of topographic highs on the Texas OCS to assess their resource value as possible commercial fishing havens or reef-type communities.

2. Pipeline corridor studies involving suitable OCS and onland areas in affected States.

3. An archeological resources survey of the Gulf of Mexico, including a preliminary determination of areas having a high probability of occurrence of such resources.

c. Baseline Environmental Data Gathering

(1) OCS Research Management Advisory Board

The OCS Research Management Advisory Board was established on March 20, 1974 by the Secretary of the Interior to aid in the design and implementation of the baseline and monitoring studies on the OCS. The functions of the Board were discussed previously; the charter is included as Appendix D . The precursor to the Board, an interagency ad hoc committee, began the work in January, 1974 that allowed that the MAFLA baseline studies to begin.

(2) Mississippi-Alabama-Florida OCS Baseline Study

The MAFLA baseline study was begun in April, 1974 and was conducted by the State University System Institutes of Oceanography (SISID). It constituted on intensive short-term effort at collecting oceanographical, biological, and geological information in the MAFLA area before the scheduled exploration activities were begun. Classical oceanographic techniques were employed in the data collection period, including water collection for microbial biomass, micronutrients, low molecular weight hydrocarbons, dissolved oxygen, organic carbon (particulate and dissolved), trace metals, particulate high molecular weight hydrocarbons, temperature, salinity, and depth, and stepped oblique tows for zooplankton using ½ meter nets with opening/closing devices. All these samplings were done on 15 meter stations and 4 control stations. Bottom sampling was accomplished on 40 master stations and 25 control stations. This sampling included the following: box cores for infaunal macrofauna, hydrocarbon analysis, trace metal analysis, total organic carbon, and sediment analysis. Bottom photography and dredges were used for characterizing epifauna and epiflora.

The samples taken during the 60 day sampling period are currently undergoing further analyses. These include the sorting and identification of organisms, sedimentological characterizations, and the chemical analyses of water, sediments, and organisms to determine the baseline levels of hydrocarbon and trace metal contamination. Quality control checks on the chemical analyses have also been provided for in the contract.

While this brief account of the program may not give a layman an idea of the scope and complexity of the sampling and analysis, it is felt that such a research effort will yeild substantive information which will provide an adequate baseline against which future changes due to oil and gas operations can be compared. The final report on this phase of the program is scheduled for completion in March, 1975.

In conjunction with the MAFLA baseline study, a contract was awarded to SUSIO, University of Alabama, University of Miami, Texas A&M University and NOAA's Atlantic Oceanographic and Meteorologic Laboratory (AOML) in Miami to compile, summarize, and present all existing hydrographic data for the eastern Gulf of Mexico. Data includes what is available from National Data Centers, published literature, unpublished research results, and personal files. This study will provide the best available analysis of the circulation patterns in the deep water of the Eastern Gulf and the continental shelf, and will show the relationship between the two. Availability of the data will enable the Bureau to plan future sampling programs in such a way as to maximize the quality of data being returned. It will also enable the prediction of spill trajectories from offshore platforms and probable impact to water column organisms as a result of a spill.

(3) Proposed Gulf of Alaska Baseline Data Gathering

A baseline environmental data gathering plan similar to the MAFLA baseline study has been proposed for the Gulf of Alaska. It is planned that NOAA, in conjunction with the Geological Survey and the Fish and Wildlife Service, will conduct the study. While some work by NOAA ships has begun, full implementation of the required sampling work awaits final approval of the FY 75 budget.

(4) Other Potential Data Gathering Programs

Environmental baseline studies similar to the MAFLA and Gulf of Alaska programs are planned for initiation in calendar year 1975 in the South Texas area, Southern California, and at some undesignated site on the Atlantic coast. The South Texas baseline study will be conducted by the Geological Survey in Corpus Christi, in conjunction with the Fish and Wildlife Service, NOAA, and Texas universities. Implementation of the sampling program in South Texas also awaits budget approval. The studies in the other areas are still in the planning stages. The FY 75 budget request for these sampling and analysis programs was $9.7 million.

d. Environmental Monitoring Programs

Environmental monitoring programs are the natural follow-up programs to the environmental baseline programs. Utilizing similar sampling and analytical techniques, and previously identified sampling sites, additional collections of organisms, sediments, and water will be accomplished after exploration (and possibly production) have begun. After analysis and data reduction, a comparison of the environmental parameters measured can be made, and an estimate of the correlation between the observed changes and the degree and proximity of oil and gas development can also be made. Monitoring studies in all geographic areas that have baseline studies will continue for several years after the onset of development, in order that the longer range impacts may be quantified. At the present time, no monitoring programs have been designed, and no contracts awarded or memoranda of understanding between agencies formulated. Preliminary planning by the Research Management Advisory Board has begun, however.

6. Requirements for OCS Facilities and Equipment

a. Recent Studies of OCS Technology and Practices

The term OCS Technology and Practices covers such a broad spectrum of individual technologies and practices that it is virtually impossible to maintain an up-to-date published study of "OCS Technology". The 378 page volume "Energy Under the Oceans - A Technology Assessment of Outer Continental Shelf Oil and Gas Operations" published in 1973 by the University of Oklahoma Press is one reference used extensively throughout this statement. Attachment of this statement is the GS comments on the recommendations made in this "Energy Under the Oceans" and comments also on recommendations made in three other reports identified in the appendix to the GS report. Preceeding all of these was the Report to the Conservation and Natural Resources Subcommittee, Committee on Government Operations House of Representatives entitled "Improved Inspection and Regulation Could Reduce the Possibility of Oil Spills on the Outer Continental Shelf" by the Comptroller General of the United States. Each year the Offshore Technology Conference (OTC) publishes the papers submitted to the conference--in 1974 there were 183 technical reports published by the OTC. In addition, there are several commercial publications reporting on worldwide offshore technology at regular intervals.

b. Requirements for Evaluation and Approval of Designs for OCS Facilities and Equipment

The OCS operator must obtain a permit before commencing various steps in the operating plan. Permits are granted by one or more of the following agencies: U.S. Geological Survey; Bureau of Land Management; U.S. Coast Guard; Office of Pipeline Safety; Environmental Protection Agency; Corps of Engineers, United States Army; Interstate Commerce Commission. The major controlling agency for operations is the U.S. Geological Survey (GS) who issues permits for drilling and workover operations and platform installations including production facilities. They also monitor pipeline operations. The Bureau of Land Management issues permits for common carrier pipelines and GS approves lease gathering lines. GS in both the Gulf of Mexico and Pacific OCS has issued a series of Operating Orders which are revised from time to time as required. The GS permits and OCS orders, in general, will provide the requirements for evaluation and approval of designs for OCS facilities and equipment.

c. Establishment of Performance Standards for OCS Facilities and Equipment

This, generally, is the same as the preceeding paragraph. The OCS Orders issued by GS will stipulate certain minimum testing requirements as well as the form and frequency of reporting both routine tests plus failures as they occur or are detected.

E. Relationship of OCS Oil and Gas Leasing to U.S. Energy Supply

1. Domestic Need for Energy

America's energy demand is a function of our present living standard, our high level of human activity, and the goals our society is striving to achieve. Energy demand magnitude thus reflects what we want to accomplish as a people. Maintaining general well-being, guaranteeing national security, and providing assistance to the less developed nations requires large amounts of energy. If our energy supplies are adequate, then we can have real freedom in selecting those objectives we wish to pursue as a nation.

Per capita energy consumption is higher in the United States than in any other country. The well-publicized disparity that Americans consume 33% of the world's total energy while comprising only 6% of its population is a consequence of this high per capita energy consumption level.

Another aspect of the domestic energy need issue is the relationship between energy demand and GNP, as demonstrated by the energy/GNP ratio which measures aggregate energy consumption versus Gross National Product. Following a trend first appearing in the 1920's, this ratio exhibited a steady decline during the period 1947-1966. These nineteen years were characterized by GNP increases that exceeded corresponding increases in aggregate energy consumption. However, since 1966, the trend has reversed and the ratio is now proceeding along an upward trajectory. (One attempt to pinpoint the causes of this change in direction (National Economic Research Associates, 1971) identifies the increasing nonenergy use of fuels, the slowdown in thermal efficiency improvement of generating stations, and the increasing importance of air conditioning and electric heating, as the major reasons for this trend reversal). The change in direction of the energy/GNP ratio is more than a statistical phenomenon worthy only of academic interest. As long as the energy/GNP ratio moved downward, economic growth corresponded with a less than proportionate increase in energy consumption; but with the present increasing ratio, economic growth acts as a multiplier on energy consumption.

Though all predictions imply uncertainty, it is reasonable to assume a continuation of the secular growth in GNP and, hence, a corresponding rise in aggregate energy consumption. It is instructive to note that human labor today provides energy for less than one percent of the work performed in the industrial and manufacturing sectors. Literally, our economy and our mode of life are totally energy dependent.

Domestic energy need can be analyzed by evaluating the energy required by the various economic sectors. In the residential sector, the trend toward owning homes - exhibited so clearly in the 1960's when population grew by 11 percent while households expanded 17 percent - will accelerate energy demand (Ford Foundation, 1974). American homes contain such energy intensive items as central heat, hot water heaters, stoves, refrigerators, and electric lights. Other energy inefficient appliances such as air conditioning, electric clothes dryers, self-cleaning ovens, frost-free refrigerators, and color televisions are becoming increasingly popular. These consumer preferences will mean that the residential sector will be an important source of expanded energy demand in the future.

The commercial sector of the economy needs energy for space heating and cooling, for lighting, and for office equipment. The energy requirements of recently constructed office buildings have shown to be relatively steep due to such features as higher lighting levels, sealed windows (necessitating twenty-four-hour mechanical ventilation), glass curtain walls (permitting high levels of heat loss and gain) as well as to the proliferation of computers, elevators, escalators, and electric office machines within the building (Ford Foundation, 1974).

The industrial sector accounted for over 40 percent of all the energy consumed in the United States during 1972. The principal consumers of energy in the industrial sector have been the primary metal industries, the chemical and allied products industry, and the petroleum refining industry. Together these groups accounted for over 50 percent of the industrial sector's energy consumption. Since these industries are crucial to the American economy, it is assumed that their contribution to total energy demand will be significant. However, the industrial sector has recently shown an admirable trend in energy efficiency. With the exception of just four sectors responsible for a combined total of less than two percent of industrial energy demand, all industrial sectors have achieved a decline in their energy per unit output ratios. (Standford Research Institute, 1971). This development explains why a recent energy demand forecast (United States Department of the Interior, 1972) predicted that the industrial sector would grow progressively less energy intensive between now and the year 2000.

The energy needs of the transportation sector are dictated in large part by the automobile. Total car miles driven in the United States have doubled every 15 years since 1940, reaching 1.2 trillion in 1972 (Motor Vehicle Manufacturers Association, 1972). Automobiles carry over 95 percent of all urban passenger traffic. Unfortunately, the average American car's efficiency has been on the wane. In 1958, the average American auto consumed less than one gallon of gasoline in travelling 14 miles; by 1973, the rate dropped to less than 12 miles per gallon (Sawhill, 1974). Automobile efficiency often declines with increased vehicle weight - and with the addition of power steering, automatic transmission, and air conditioning, American cars are heavier and less efficient. In addition to the auto's intra-urban responsibility, cars account for over 85 percent of all inter-city passenger traffic, while the most efficient transportation modes - railroads and buses - carry only 3 percent. Airplanes are becoming increasingly popular in both freight and passenger transport even though the airplane is the least energy efficient transport form. Automobile popularity and increasing use of the airplane mean that the transportation sector will need growing amounts of fuels inputs as energy intensity advances due to greater reliance on the two most inefficient modes of transport.

If current trends in life-styles continue, then it seems likely that there will be increasing demands on available energy suppliers in the future. This conclusion can also be projected from the upward trend in the energy/GNP ratio since 1966.

2. Current Domestic Energy Situation

The American energy situation today is characterized by the discrepancy between the level of domestic consumption and the level of domestic production. The gap between the amount of energy the nation demanded and the amount the nation produced started to widen in the 1960's and has continued until the present. Consumption has advanced rapidly while domestic fuel production has actually been constant since 1970. Energy Consumption Growth has been encouraged by a number of factors, relative price being one of the most crucial influences. The price of energy, as compared to the prices of other goods and services, actually declined during the 1960's.

Another contributory influence toward expanded energy use during the past 14 years was the rate contracts offered by the gas and electric utilities. These contracts awarded large volume, long term users with significantly lower prices per BTU than those paid by the small volume, short term users. Interruptible contracts have encouraged natural gas use because the price at which the gas is supplied reflects only the variable costs incurred by the producer.

The period following the 1960's has also seen a tremendous increase in the amount of advertising devoted to high energy consuming goods. During these same years the automobile has achieved dominance over all alternative transportation modes. This development has been encouraged by constructing the ubiquitous interstate highway system. In addition, the drop in air fares relative to those charged for buses and train transport has promoted this energy-inefficient mode of conveyance.

While these influences have been fostering energy consumption, other factors have acted to constrain domestic energy production. The foreign tax credit spurred foreign oil production because it allowed U.S. companies to deduct payments made to host government from their taxable U.S. income. The regulation of natural gas prices and the 1969 reduction in the oil depletion allowance have been viewed as anti-productive by the industry. The 1971 imposition of fuel price controls has also been considered injurious to production. The Coal Mine Health and Safety Act of 1969 may have contributed to reduced underground coal mine productivity while the National Environmental Policy Act of 1969 may have postponed offshore lease sales and nuclear power plant construction by requiring detailed environmental impact statements prior to the initiation of any energy related environmental project.

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These actions were designed to establish a more equitable corporate tax code, stabilize a rapidly expanding economy, protect the welfare of the underground coal mines, and to safeguard the environment. These policies were not intended to impede production. Unfortunately, implementing these programs may have lowered energy availability in some cases.

3. Projections of Growth in Energy Demand

With the advent of the "energy crisis", the number of energy demand forecasts has increased significantly. The energy growth projections developed by The National Petroleum Council, The Ford Foundation, and The Department of the Interior will be reviewed in summary here.

The National Petroleum Council developed three alternative energy growth forecasts for the 1971-1985 period. These three projections were derived by making different quantitative assumptions concerning economic growth, energy costs, demographic changes, and the use of energy for environmental protection. These four variables were identified as being critical in determining long-term energy demand outlook. Given this framework - the high, intermediate, and low projections of annual percentage gain in national energy demand were 4.4, 4.2, and 3.4 respectively (National Petroleum Council, 1972).

The Ford Foundation projections are in fact three scenarios for the future based on different assumptions concerning energy growth rate. The historical growth scenario envisions a resumption of the 3.4 percent per year energy growth rate established between 1950 and 1972. Achieving this rate is predicated on the implementing of consumption and production maximizing policies, relaxing all developmental constraints, increasing our reliance on coal and uranium, and expanding our energy research efforts.

The technical fix scenario is based on an energy growth rate equal to one-half that of historical precedence. This could be accomplished by stressing conservation and consumption efficiency while concurrently deemphasizing production.

The third and final scenario proposed by the Ford Foundation is a zero energy growth scenario. This projection was included as a possibility because: (1) supplying energy at the 3.4% or even the 1.7% growth rate level will involve a tremendous strain on our current technology and resources (2) the earth's capacity for sustaining environmental injury has an upper limit and (3) restricting the energy growth of the rich nations may be the only way to increase living standards in the less developed nations. Given the right conditions, the transition to zero energy growth could be achieved without economic dislocation and with only limited government direction. The trend toward voluntary zero population growth is a step in this direction.

The energy forecast constructed by the United States Department of the Interior is presently being revised and updated. The original 1972 projection predicted mean annual energy growth rate of 3.6 percent for the 1971-2000 period. However, preliminary indications reveal that the modified forecast will show a lower rate.

Considering the three different energy forecasts reviewed above, a guarded estimate of a two to three percent increase rate in energy use for the 1971-2000 interval appears reasonable. This range is somewhat less than the growth rate experienced between 1950 and 1972 and is significantly less than the rate of increase achieved during the late 1960's and early 1970's. Nevertheless, achieving a two to three percent increase in energy growth over the next 25 years will require innovative planning and utilization of our human and technical resources.

4. Availability of Energy Sources of Supply (Not Including Conventional Oil and Gas Supplies)

a. Coal

It has been estimated that the United States has coal resources equal to 3.21 trillion tons, or over half the world's known supply. (Averitt, 1967). This estimate has been broken down in the following manner:

	Trillion Tons
Mapped and Explored Areas with 0-3000 ft. overburden	1.56
Probable Additional Resources in Unmapped and Unexplored Areas	
at 0-3000 ft. Depth	1.31
at 3000-6000 ft. Depth	0.34
Total	3.21

(Source: National Petroleum Council, 1973)

U.S. coal resources occur in three general areas: the Appalachian areas, the mid-continent region, and the eastern Rocky Mountain region. West Virginia and Pennsylvania have the greatest remaining measured and indicated underground coal reserves as well as economically extractable reserves. The second greatest concentration is located in the Illinois-Indiana-Ohio region. The greatest amount of recoverable surface coal is found in Colorado, Montana, New Mexico, and Wyoming.

b. Synthetic Sources of Oil and Gas

(i) Oil Shale

The abundant oil shale resources of the United States offer great potential as an energy supply supplement to conventional oil and gas sources. Oil shale deposits are located throughout much of the country, but many are low grade, small, and inaccessible. The richest deposits occur in the Green River Formation in Colorado (80%), Wyoming (5%) and Utah (15%). These concentrations are found in large topographic basins that are identified by streams draining most of the land surface. The following table provides a U.S. Geological Survey estimate of United States oil shale resources.

Table 6. Oil Shale Resources

eposit	Identified* 25-100 gal/ton	Identified* 10-25 gal/ton	Hypothetical** 25-100 gal/ton	Hypothetical** 10-25 gal/ton
reen River Formation, Colorado Utah, Wyoming	418	1,400	50	600
hattanooga Shale and equivalent formations, central and Eastern U.S.		200		800
arine Shale, Alaska	small	small	250	200
ther Shale deposits		small	NE***	NE

*Identified resources refer to specific, identified mineral deposits that may or may not be evaluated as to extent and grade and whose contained minerals may or may not be profitably recovered with existing technology and economic conditions. This category is roughly equivalent to "average of 30 or more gallons per ton".

**Hypothetical resources refer to undiscovered mineral deposits, whether of recoverable, or subeconomic grade, that are geologically predictable as existing in known districts.

**Not estimated.

U.S. Geological Survey, U.S. Mineral Resources, 1973, p. 500 (USGS Professional Paper 820).

(ii) Synthetic Gas and Oil

Through hydrogenation processes, it is possible to convert coal to various liquid and gaseous substitutes for fuel oil and natural gas. The Department of the Interior gives the following forecasts for synthetic gas production.

Year	Total Gas Produced		Energy Inputs	
	bil. cu. ft.	Tril. btu	Coal mil. tons	Petroleum mil. bbl.
1980	700	700	19	84
1985	2,000	2,000	86	128
2000	5,500	5,500	308	105

One 250 billion Btu per day coal gasification plant will require about six million tons of coal annually. The availability of light hydrocarbon supplies as well as the availability of refining capacity to produce feedstocks for gasification is questionable. (There has been much rethinking about petroleum - based synthetic gas plants and many plans have been shelved). About 20 to 25 thousand barrels of hydrocarbon, feedstock will be required to produce 100 million cubic feet of synthetic gas.

c. Hydroelectric Power

Hydroelectric processes harness the energy of natural or regulated streamflows created by dams and waterways in order to produce electric power. The total conventional hydroelectric power

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potential of the U.S. at both developed and undeveloped sites is estimated to be about 702 million kilowatt hours of electricity annually. Of this total, 429 million kilowatt hours (per annum) had not been developed as of January 1972. However, many of the best hydroelectric sites have already been developed.

The table on the following page shows conventional developed and undeveloped hydroelectric capacity in the United States.

d. Nuclear Power

Producing electricity from nuclear generators has a sizable impact on the power industry in the United States. The most developed nuclear processes are heavy uranium or uranium-derived metal fissioning methods. The AEC develops estimates of two types of uranium concentrations. "Reserves" indicate known deposits that can be economically produced at a given market price. "Potential resources" signifies deposits not yet discovered, unexplored extensions of known deposits, and identified deposits that cannot now be recovered. These categories are influenced by the prevailing market price. For example, lower market price based estimates are more precise because they reflect industry's past exploration experience. Uranium concentrations are measured in terms of tons (or pounds) of U_3O_8, the oxide precipitated from the naturally occurring ore.

Table 7. . Hydroelectric Power Resources of the United States by Geographic Divisions

Area 1/	Developed 2/		Undeveloped		Total Potential 3/		Percent Total potential capacity now developed	Percent Total potential generation now developed
	Capacity (MW)	Average annual generation (million Kwhrs)	Capacity (MW)	Average annual generation (million Kwhrs)	Capacity (MW)	Average annual generation (million Kwhrs)		
New England	1,480	5,087	3,349	8,325	4,829	13,412	30.6	37.9
Middle Atlantic	5,967	28,851	2,625	9,038	8,592	37,889	69.4	76.1
East North Central	839	4,279	1,410	5,455	2,249	9,734	37.3	43.9
West North Central	3,089	14,325	3,966	14,002	7,055	28,327	43.7	50.5
South Atlantic	5,505	17,480	8,957	16,785	14,462	34,265	38.0	51.0
East South Central	5,259	25,160	3,843	3,287	9,102	28,447	57.7	88.4
West South Central	2,279	3,921	2,846	7,286	3,125	11,207	44.4	34.9
Mountain	6,601	39,276	25,792	80,670	32,393	119,946	20.3	24.4
Pacific Contiguous	25,467	143,987	36,274	101,238	62,191	245,225	40.9	58.7
Pacific Non-contiguous	80	368	32,529	172,687	32,609	173,055	.2	.2
Total U.S.	56,566	272,734	122,041	428,773	178,607	701,507	31.6	38.8

1/ New England Area includes Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut. Middle Atlantic Area includes New York, New Jersey, Pennsylvania. East North Central Area includes Ohio, Indiana, Illinois, Michigan, Wisconsin. West North Central Area includes Minnesota, Iowa, Missouri, N. Dakota, S. Dakota, Nebraska, Kansas. South Atlantic Area includes Delaware, Maryland, Washington, D. C., Virginia, West Virginia, N. Carolina, S. Carolina, Georgia, Florida. East South Central Area includes Kentucky,Tennessee, Alabama, Mississippi. West South Central Area includes Arkansas, Louisiana, Oklahoma, Texas. Mountain Area includes Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada. Pacific Contiguous Area includes Washington, Oregon, California. Pacific Non-contiguous Area includes Alaska, Hawaii.

2/ Federal Power Commission News Release No. 19370, June 27, 1973. Data to December 31, 1972.

3/ Federal Power Commission, Hydroelectric Power Resources of United States, Developed and Undevaloped, January 1, 1972.

Below are recent estimates of domestic uranium concentrations.

Table 8. PRODUCTION, RESERVES, AND POTENTIAL COMPARED TO REQUIREMENTS

Tons U_3O_8

	1948-1971 Production	Cut-off Cost	Reserves	Potential	Total	Total Reserves and Potential
mbrosia Lake, New exico (the largest . S. uranium district)	64,000	$ 8	58,000	29,000	151,000	87,000
		$15	87,000	59,000	210,000	146,000
ther New Mexico	31,000	$ 8	79,000	196,000	306,000	275,000
		$15	113,000	393,000	537,000	506,000
yoming	43,000	$ 8	95,000	100,000	238,000	195,000
		$15	164,000	275,000	482,000	439,000
ther U. S.	97,000	$ 8	41,000	135,000	273,000	176,000
		$15	156,000	273,000	526,000	429,000
otal U. S. A.	235,000	$ 8	273,000	460,000	968,000	733,000
		$15	520,000	1,000,000	1,755,000	1,520,000

(Source: Nininger, 1973)

e. Energy Imports

(i) Oil Imports

Until domestic energy self-sufficiency is attained, oil imports will play a crucial role in our country's energy mix. Given the assumptions presented in the section entitled *Projections of Growth in Energy Demand*, the table below provides estimates of the expected demand for petroleum, the predicted domestic production at normal growth rates and the supplemental supplies that the projected demand levels will necessitate. These auxiliary quantities will initially be furnished by imports. However, as domestic energy production is stimulated under Project Independence, the magnitude of these imports should decline. If domestic self-sufficiency is achieved by 1980, then the number of barrels of oil imported at that time will be reduced significantly.

Table 9. Total U.S. Petroleum Demand Domestic Production and Supplemental Supplies Through 2000 (million barrels/day)

	1971	1975	1980	1985	2000
Total Petroleum Demand	15.1	17.4	20.9	25.0	35.6
Total Domestic Production	11.3	11.0	11.8	11.6	10.6
Supplemental Supplies	3.8	6.4	9.1	13.4	25.0

Source: *U. S. Energy Through the Year 2000*, U. S. Department of the Interior, December, 1972, p. 43.

(ii) Natural Gas Imports

Natural gas imports are available to the United States via pipeline from Canada or Mexico or as tanker borne liquefied natural gas (LNG) from other countries. In 1972, Canada supplied the U.S. with 1.0 trillion cubic feet of pipeline transported natural gas, while Mexico exported 0.008 trillion cubic feet to this country. Mexico's small natural gas reservoir and her professed policy of energy self-sufficiency, mean that the probability of increasing imports from this source are indeed slim.

Prospects for Canadian imports have improved because of recent gas reservoir discoveries in the Arctic Islands, Mackenzie Valley, and the Atlantic Offshore regions. These deposits, however, are not incorporated into the projections reproduced below because the Canadian National Energy Board will not recognize these resources until their development has progressed to an economically feasible level.

Table 10. Pipeline Imports from Canada
(Trillion cubic feet)

	1975	1980	1985
FPC projection	1.2	1.6	1.9
USDI projection	2.0	3.0	4.1
NPC projection	1.0	1.6	2.7

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Natural gas can be converted to a liquid when subjected to a temperature of -259°F at standard atmospheric pressure. This technique allows natural gas to be shipped between locations whose connection by pipeline would be physically arduous. Large scale shipping of liquefied natural gas (LNG) is a relatively new industry and the United States presently lacks facilities for receiving LNG shipments. Two developmental projects have been approved by the FPC while others are pending. Further LNG import levels naturally depend on the rate at which receiving facilities are constructed. The following table provides three estimates of future LNG imports.

Table 11 Estimated LNG Imports
(Trillion cubic feet)

	1975	1980	1985
FPC projection	0.3	2.0	3.0
USDI projection	0.5	0.9	1.6
NPC projection	0.24	2.28	4.11

f. Other Energy Sources

(i) Geothermal Energy

This kind of energy is derived from the heat generated by the radioactive decay of uranium, thorium, and potassium within the earth's crust. Geothermal energy was not tapped in the United States until 1955 when the Geysers area, 75 miles north of San Francisco, was drilled. Geothermally leased power was first generated in 1960 at the rate of 12,500 kilowatts/year. Today this rate is in excess of 400,000 kilowatts/year, making the U.S. the largest geothermally derived power producer in the world.

The greatest geothermal energy potential in the United States exists in the Rocky Mountains and the Pacific regions. Along the Gulf Coastal Plain of Texas and Louisisna there also exists possible development potential. California leads the Nation in developing geothermal energy. The Geysers field will supply in 1974 enough steam to four electric generating plants to result in the production of 552 megawatts (MW) of electricity. By 1995 geothermal energy could account for 1 to 2 percent of the country's energy needs.

(ii) Tar Sands

In some regions, petroleum occurs as a liquid so viscous that it is almost solid. These concentrations are referred to as "tar sands", the tar being a distillation product rather than a naturally occurring substance.

Utah, California, and Kentucky are the only States with known tar sand deposits. Only Utah's concentrations are recognized as having production potential, however, these deposits are not recoverable by mining and in situ methods will have to be used. The in situ technology has not advanced to an operable state, one potent obstacle being the lack of a sufficient water supply proximate to the deposits.

Even if the necessary recovery methods could be implemented today, other problems exist. The major U.S. tar sand concentrations occur on Federal lands designated for use as desert wilderness areas, recreational use areas, national parks, or national monuments. Tar sand development would conflict with these intended uses and would thus require a legal endorsement.

(iii) Hydrogen

Hydrogen is the most abundant of all elements accounting for 75 percent of the mass of the universe. Though plentiful, hydrogen usually occurs in chemical combination with one or more different elements. Combusting hydrogen for energy purposes is thus hindered since the hydrogen must first be separated from the compound in which it is naturally found. Hydrogen's potential uses as a fuel are many. Hydrogen may be used in the internal combusion and jet engines as well as being used as an auxiliary fuel in steam electric plants.

Hydrogen will definitely serve as an energy source some day in the future. Presently, the technical obstacles attending its use prevent its immediate utilization.

(iv) Biological Energy

This energy source refers to producing ethyl alcohol from carbohydrate concentrating farm crops and the conversion of organic wastes into oil. The major present obstacle to biological energy is economic. Agriculturally derived ethyl alcohol would be many times the cost of today's motor fuel while the treatment procedure necessary to convert organic waste into oil is similarly exorbitant. Nevertheless, unculivated farmland could produce a volume of ethyl alcohol equivalent to 14 percent of the motor fuel energy consumed in the U.S. in 1970. Additionally, the organic waste we generated in 1971, could have been converted to 170 million barrels of oil. This conclusion is illustrated in Table 12.

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Table 12

	Estimates of Organic Wastes Generated, 1971 and 1980		1971 Organic Solids Available for Conversion
	1971	1980	
Source:			
Manure	200	266	26.0
Urban refuse...do.	129	222	71.0
Logging and wood manuf. residues...do.	55	59	5.0
Agriculture crops and food wastes 15)..do.	390	390	22.6
Industrial wastes...do.	44	50	5.2
Municipal sewage solids...do.	12	14	1.5
Miscellaneous organic wastes...do.	50	60	5.0
Total...do.	880	1,061	136.3
New oil potential...million barrels	1,098	1,330	170
Net gas for fuel potential...tril. cu.ft.	8.8	10.6	1.36

(v) Solar Energy, Tidal Power, Wind Energy

Harnessing the energy of the sun, the tides, and the winds is currently under extensive investigation. All three possible sources appear to be eventual contributors to our domestic energy supply thus current interest is keen. The availability of these three sources is evident, but the key concern focuses on overcoming the technical obstacles hindering conversion to usable energy. Solar energy is currently being used as a power source in a few pilot programs. High initial capital outlays have prevented the construction of any tidal power plants but additional study is planned. The National Aeronautics and Space Administration (NASA) plans to build a large windmill at Sandusky, Ohio. NASA predicts that windmills could supply between 5 and 10 percent of the United States' total electric power needs by the year 2000.

5. Oil and Gas Resources*

Estimating domestic oil and gas resources is an undertaking fraught with uncertainty. Assumptions concerning the hydrocarbon reservoir of the Atlantic Continental Shelf, where not a single hole has been drilled, or the resource concentrations of unexplored onshore terrain have to be regarded as highly speculative. These qualifications should be kept in mind when analyzing any estimate of domestic resources. Nevertheless, the estimates of the United States Geological Survey (March 26, 1974) incorporated highly specialized geophysical data that heretofore was unavialable. These USGS estimates are the basis of the following discussion.

According to the most recent published figures of the USGS (see following chart), cumulative crude oil and natural gas liquid production through 1972 amounted to 115.27 billion barrels of oil and 437.72 trillion cubic feet of gas. The latest estimate of total measured reserves in the United States claims 48.3 billion barrels of crude oil and natural gas liquids plus 266.1 trillion cubic feet of gas. Measured reserves are defined as identified reserves from which an energy commodity can be extracted with existing technology and present price conditions. The location, quality, and quantity of measured reserves are known from geologic data and are confirmed by engineering data. Consequently, estimates of measured reserves are in the form of point - rather than interval - estimates.

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* The term "resources" indicates materials that have been identified, but cannot now be extracted because of economic or technological factors as well as economic or subeconomic materials that have not yet been discovered. "Reserves" are deposits known to be recoverable with present technology and existing price levels. "Resources" is the broader of the two terms and encompasses all deposits classified as "reserves".

Indicated and inferred reserves are predicted to fall somewhere in the 25-45 billion barrel range for crude oil and natural gas liquids, and in the 130-250 trillion cubic feet range for gas. Estimates of indicated and inferred reserves do not convey the same degree of certainty as measured reserves and interval estimates are therefore appropriate. Indicated reserves are determined in part by specific measurements, samples, and production data, and in part by projections based on geologic data. Inferred reserves are derived from broad geologic knowledge for which corresponding quantitative data is not available. Inferred reserves are those estimated to be recoverable in the future as a result of revising and extending present estimated figures as well as deeper drilling in known fields. The following table does not differentiate between indicated and inferred reserves.

The final resource category, undiscovered recoverable resources, is the most uncertain of the estimate classes and thus exhibits the widest estimate intervals and the highest variability. Undiscovered recoverable resources are defined as reservoirs believed to exist in amenable geologic settings, but which have not been verified by

CRUDE OIL AND NATURAL GAS LIQUIDS
(Billions of barrels)

AREA	PRODUCTION				RESERVES				RESOURCES**	
	1972		CUMULATIVE end 1972		MEASURED***		INDICATED-INFERRED		UNDISCOVERED RECOVERABLE	
	State	Federal	State	Federal	State	Federal*	State	Federal*	State	Federal
Conterminous states onshore	3.100	0.214	104.200	5.577	29.3	1.7	16.0 - 27.0	1.0 - 1.5	100 - 200	10 - 20
Alaska onshore	0.000	0.009	0.000	0.134	9.6	0.1	5.0 - 10.0	0.0	20 - 40	5 - 10
Total onshore	3.100	0.223	104.200	5.711	38.9	1.8	21.0 - 37.0	1.0 - 1.5	120 - 240	15 - 30
Atlantic offshore	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	2 - 4	8 - 16
Gulf of Mexico offshore	0.100	0.390	0.700	2.770	0.5	3.5	0 - 0.5	2.0 - 3.0	2 - 4	18 - 36
Pacific offshore	0.100	0.020	1.300	0.090	0.7	2.2	0 - 0.5	1.0 - 2.0	1 - 2	4 - 8
Alaska offshore	0.100	0.000	0.500	0.000	0.7	0.0	0 - 0.5	0.0	2 - 4	28 - 56
Total offshore	0.300	0.410	2.500	2.860	1.9	5.7	0 - 1.5	3.0 - 5.0	7 - 14	58 - 116
Total on- and offshore	3.400	0.630	106.700	8.570	40.8	7.5	21.0 - 38.5	4.0 - 6.5	127 - 254	73 - 146

NATURAL GAS
(Trillions of cubic feet)

Conterminous states onshore	17.700	1.001	397.400	16.870	175.7	14.1	86.0 - 164.0	7.0 - 13.0	450 - 900	50 - 100
Alaska onshore	0.000	0.056	0.000	0.307	26.4	2.1	13.0 - 26.0	1.0 - 2.0	80 - 160	25 - 50
Total onshore	17.700	1.057	397.400	17.177	202.1	16.2	89.0 - 190.0	8.0 - 15.0	530 - 1060	75 - 150
Atlantic offshore	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	5 - 10	50 - 100
Gulf of Mexico offshore	0.600	3.030	3.900	17.400	6.5	36.8	3.0 - 5.0	18.0 - 36.0	10 - 20	150 - 300
Pacific offshore	0.000	0.010	1.200	0.040	0.7	2.0	0.0 - 0.5	1.0 - 2.0	5 - 10	5 - 10
Alaska offshore	0.100	0.000	0.600	0.000	1.8	0.0	1.0 - 1.5	0.0	20 - 40	150 - 300
Total offshore	0.700	3.040	5.700	17.440	9.0	38.8	4.0 - 7.0	19.0 - 38.0	40 - 80	355 - 710
Total on- and offshore	18.400	4.100	403.100	34.617	211.1	55.0	103.0 - 197.0	27.0 - 53.0	570 - 1140	430 - 860

*Distribution between State and Federal is based on assumption that reserves are in the same ratio between the two as recent production.

**As shown by the range, unit figures have little significance for individual areas, but merely show the approximate distribution of the rounded total for the United States--200-400 billion barrels of petroleum liquids and 1,000-2,000 trillion cubic feet of natural gas.

***Total U.S. measured reserves derived from American Petroleum Institute and American Gas Association.

Estimates revised: Feb. 14, 1974

drilling. Undiscovered recoverable resources are estimated to be in a range of 200 to 400 billion barrels of crude oil and natural gas liquids, while gas is believed to fall within the 130-250 trillion cubic feet range.

6. OCS Oil and Gas Resources

OCS oil and gas resource estimates have also been calculated by the USGS. These estimates are grouped amoung the same categories as the total domestic resource estimates. (See preceeding chart) Resources located in water whose depth exceeded 200 feet were not included in the estimate calculations.

Measured reserves (see preceeding section for exact definition) are set at 7.6 billion barrels of crude oil and natural gas liquids while the corresponding figure for natural gas is 47.8 trillion cubic feet. Indicated and inferred reserves for the lands submerged in less than 200 feet of water are estimated to range between 3 and 5 billion barrels of crude oil and natural gas liquids. For natural gas, the appropriate offshore interval is between 23 and 45 trillion cubic feet. Finally, undiscovered recoverable crude oil and natural gas liquid resources are presumed to be between 65 and 130 billion barrels for crude oil and natural gas liquids and between 395 and 790 trillion cubic feet for natural gas.

7. Brief History of OCS Oil and Gas Leasing Program

Section 8 of the Outer Continental Shelf Lands Act of August 7, 1953, authorizes the Secretary of the Interior to issue mineral leases on the Outer Continental Shelf. The act stipulates that oil and gas leases may be issued on a competitive bidding basis as required by the following two alternatives: sealed cash bonus bids with fixed royalty or sealed royalty bids with fixed cash bonus. The Bureau of Land Management (BLM) administrates the leasing objectives of the OCS Lands Acts in accordance with three goals:

(1) orderly and timely resource development
(2) protection of the environment
(3) receipt of fair market value

The United States Geological Survey plays a crucial role in the execution of the OCS leasing program. Prior to a sale, the USGS compiles and analyzes geological data so that an accurate valuation of the tracts offered (for sale) can be made. The values so derived are the governmental standards against which the adequacy of the high bids are evaluated.

The first oil and gas sale on the Outer Continental Shelf was held on October 13, 1954. Under the cash bonus scheme, 199 tracts off the coast of Louisiana were offered for competitive bidding. The revenues realized by the government totalled over $116 million. There have been 34 OCS oil and gas sales since 1954. The cash bonus method was used in all of these sales.

Until 1970, leasing strategy on the Outer Continental Shelf was governed by the excellent productive capacity for petroleum and natural gas onshore in the United States. Orderly and timely resource development dictated that offshore production opportunities had to be made available at a rate that would not jeopardize existing onshore activity. Thus, from 1954 to 1970, only 7.2 million acres on the Outer Continental Shelf were placed under lease.

The voracious demand for energy has changed our outlook toward domestic resources. Since the beginning of this decade, it has been evident that the cautious OCS policy of the 1950's and the 1960's would contribute to serious supply deficiences in domestic energy. In the past three years, 1.9 million acres have been leased on the OCS - over a quarter of the total amount leased during the previous 17 years. Recent lease sales have been followed rapidly by actual drilling of the tracts leased. Thus, as a result of these sales, increased production should soon follow.

8. Current Production From the OCS Oil and Gas Leasing Program

The Outer Continental Shelf has produced oil and gas for domestic consumption since 1954. In 1973, oil production averaged

1,081,000 barrels a day or roughly 8 percent of average daily domestic consumption during that year. Of this, 1,029,000 barrels a day came from wells in the Gulf of Mexico. The remaining 52,000 barrels a day were produced from fields off southern California. Daily OCS gas production totalled 8.9 billion cubic feet in 1973. All but 20 million cubic feet a day came from the Gulf of Mexico.

DESCRIPTION OF THE ENVIRONMENT

A. Description of the Offshore Environment

1. Atlantic Region

a. Geology

The Atlantic Continental Shelf represents a natural seaward extension of the onshore Atlantic Coastal Plain, a gently-dipping wedge of Mesozoic[1] and Cenozoic sedimentary strata stretching over an area of more than 100,000 square miles from southern New England to southern Florida. The Coastal Plain narrows northwards from a width exceeding 150 miles in Georgia to less than 50 miles in northern New Jersey. To the west, it terminates abruptly against pre-Mesozoic crystalline rocks of the Appalachian Piedmont Plateau.

Offshore, the continental shelf, slope and rise comprise the Atlantic continental margin of North America (Fig. 1). Uchupi (1970) divided this offshore region into a northern physiographic segment extending from Nova Scotia southward to Cape Hatteras, North Carolina and a southern segment between Cape Hatteras and the Florida Keys. The northern segment is characterized by a 'normal' continental margin progression. The relatively-smooth, gently-dipping shelf extends seaward to a water depth of 100 to 200 meters; a break at this depth marks the beginning of the more steeply-inclined continental slope. At the foot of the slope, regional declivity decreases onto the continental rise which slowly descends from a water depth of

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1/ A geologic time chart is enclosed for reference as Figure 2.

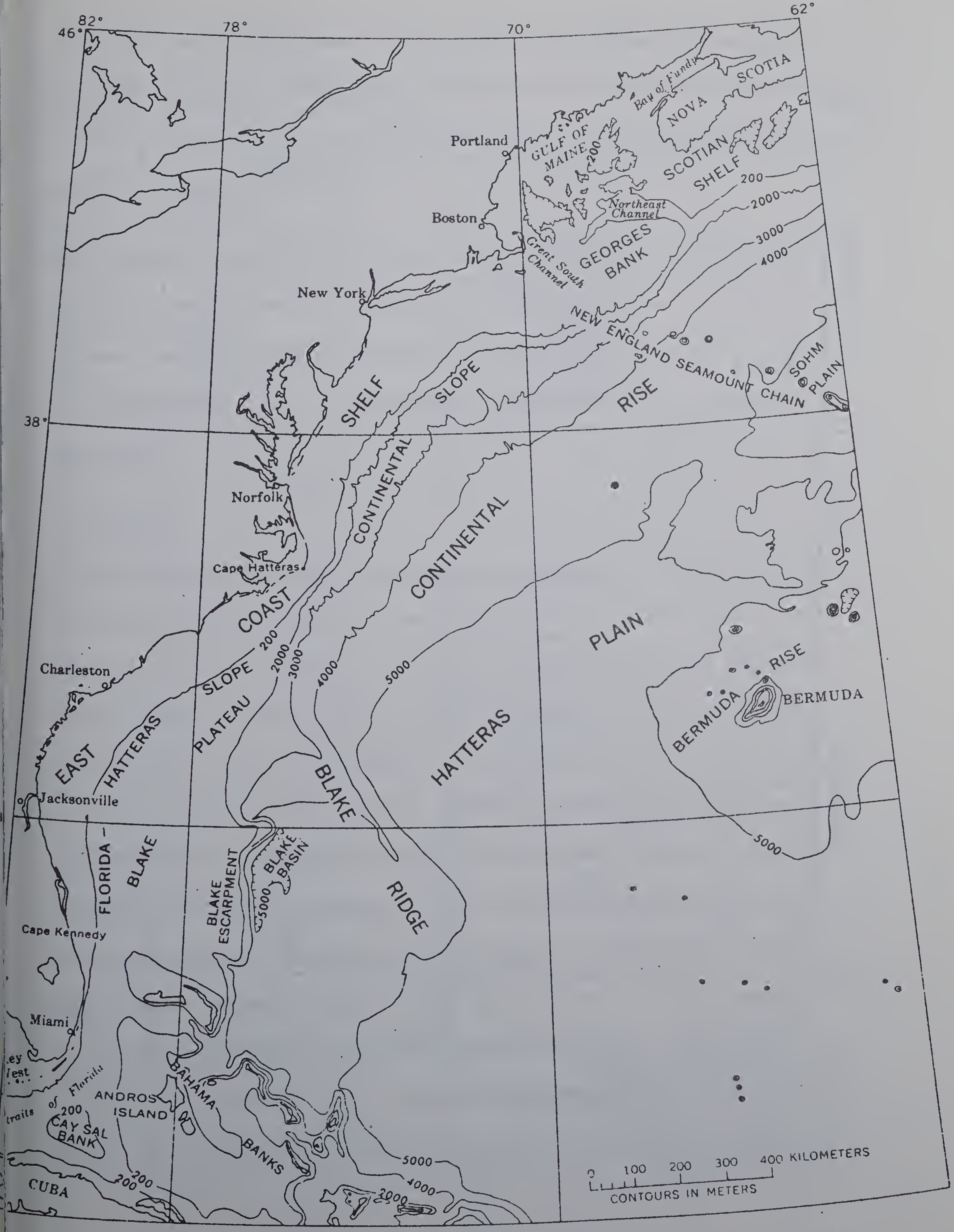

FIGURE 1 –Physiographic provinces of the continental margin off the east coast of the United States. (from Uchupi, 1970).

Figure 2. GEOLOGIC TIME CHART

AGE DIVISIONS			TIME			
ERA	PERIOD	EPOCH	DURATION IN MILLIONS OF YEARS			BEGINNING MILLIONS O YEARS AGO
			ERA	PERIOD	EPOCH	
CENOZOIC	QUATERNARY	RECENT	63.011	1.011	0.011	0.011
		PLEISTOCENE			2	2
	TERTIARY	PLIOCENE		62	12	13
		MIOCENE			12	25
		OLIGOCENE			11	36
		EOCENE			22	58
		PALEOCENE			5	63
MESOZOIC	CRETACEOUS		167	72		135
	JURASSIC			46		181
	TRIASSIC			49		230
PALEOZOIC	PERMIAN		370	50		280
	PENNSYLVANIAN			40		320
	MISSISSIPPIAN			25		345
	DEVONIAN			60		405
	SILURIAN			20		425
	ORDOVICIAN			75		500
	CAMBRIAN			100		600
PRE-CAMBRIAN	GRENVILLE OROGENY		4000			1000
	OLDEST KNOWN ROCKS IN NORTH AMERICA					3200
	OLDEST KNOWN ROCKS (MURMANSK AREA)					3400
	PROBABLE AGE OF THE EARTH					4600

2000-3000 meters to oceanic basin depths exceeding 5000 meters. Regional gradients within the continental slope province vary from 2° to 7°; while values for the shelf and rise are generally less than 0°10' and 1°, respectively.

The southern segment of the east coast continental margin differs from that to the north in possessing a sub-province, the Blake Plateau, which intervenes between the continental shelf and slope. The continental rise is essentially missing from this southern sequence.

Structure

In general terms, seismic profiling data reveal variations in the velocity of sound energy transmission through rock strata. Since many physical properties of rocks (e.g. mineralogic and textural composition, porosity, fluid content, degree of compaction and alteration) interact to produce a particular velocity profile, the interpretation of seismic data, without confirmative drilling information, is frequently difficult. Seismic data will, however, generally reveal a 'basement' layer or sub-bottom surface that strongly reflects seismic energy and that is construed to have once been a regional depositional surface now overlain, commonly to great thicknesses, by sedimentary rock strata. The terms 'effective basement' and 'economic basement' refer to the subsurface layer within and below which oil and gas will probably not be found.

While mapping the configuration of the basement surface can be highly interpretive, the delineation of this datum or reference surface allows more meaningful structural interpretation and subsequent evaluation of subsurface resource potential.

While some investigators (e.g., Mayhew, 1974) prefer to use purely geophysical criteria (seismic velocities) in defining basement beneath the Atlantic OCS, this surface can be alternatively taken as the top of the pre-Cretaceous. Beneath the Atlantic coastal plain and continental shelf, this pre-Cretaceous basement surface slopes increasingly seaward, with structural contours broadly paralleling the Appalachian Mountain System. Towards the coast and offshore, this trend is interrupted by several prominent structural features: the positive Cape Fear and Peninsular Arches and the negative Salisbury and Southeast Georgia Embayments. Figure 3 shows these and other major structural elements of the western Atlantic margin.

The seaward-thickening wedge of Mesozoic and Tertiary strata off the Atlantic Coast fills a depositional trough beneath the shelf which is bounded on the east by a deeply-buried basement ridge (Drake, et. al., 1959). This ridge extends along the outer shelf margin and separates the inner sedimentary trough from an outer, deeper trough located beneath the continental slope and rise. Regional thickenings occur along several portions of the inner

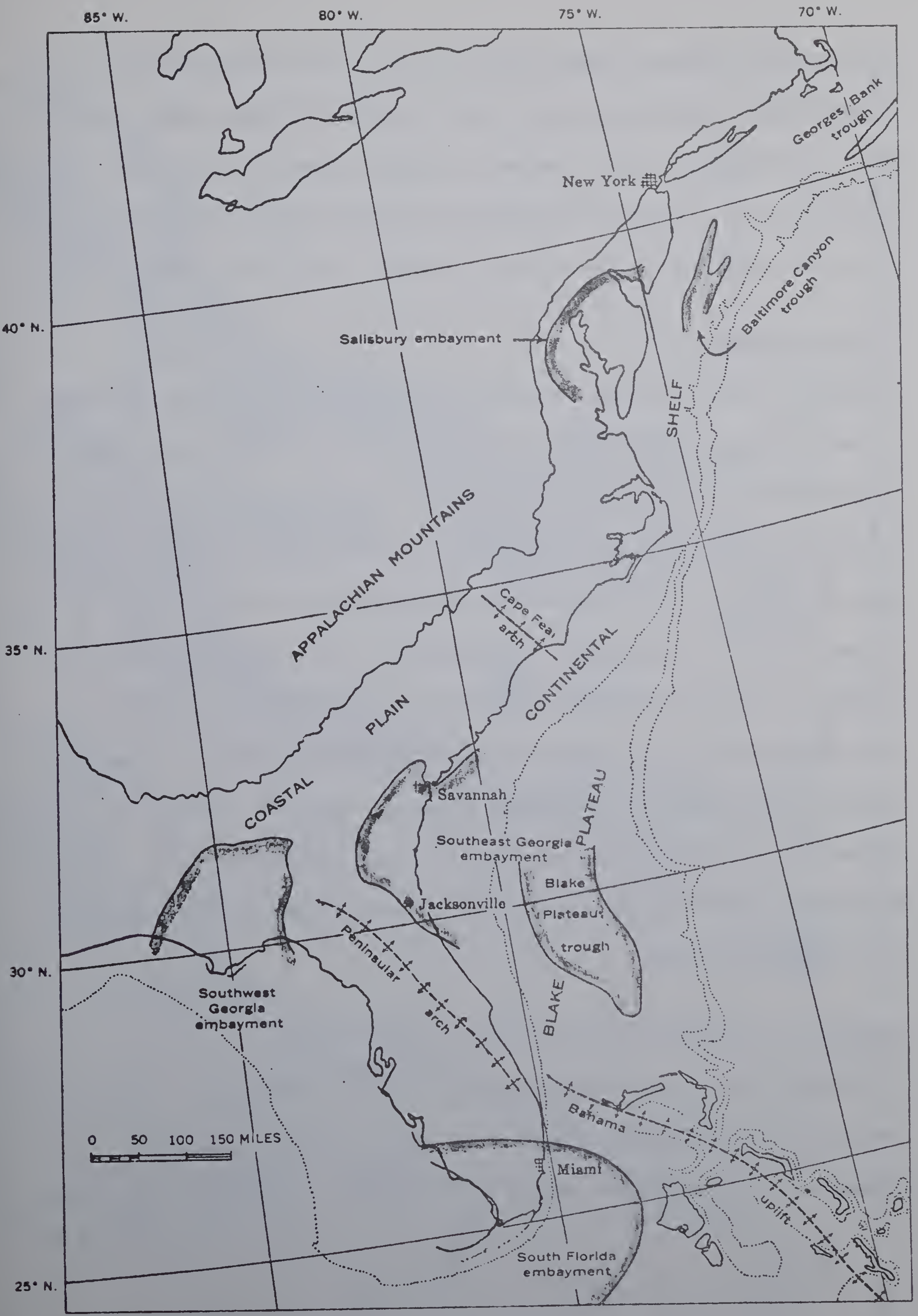

FIGURE 3 —Index map of Atlantic Coastal Plain and Continental Shelf showing principal structural features (modified from Maher, 1971).

depositional trough. These areas include the Baltimore Canyon, Georges Bank, and Emerald Bank (Sable Island) troughs (Maher, 1965; Maher and Applin, 1971). Basement contours beneath the Blake Plateau reveal a broad, northward-trending structural depression that is more than 6 km deep and is appropriately called the Blake Plateau trough.

Bottom Sediments

Figure 4 gives the general distribution of sediment types off the Atlantic Coast, with respect to texture, contributing agent and age. Textural complexity is most apparent in the northeastern areas, particularly in the glaciated and ice-rafted relict sediments of the Gulf of Maine. From Georges Bank southwestward, relict sands dominate much of the shelf. Modern clastic (land-derived) sands are generally restricted, north of Cape Hatteras, to a narrow nearshore zone. South of the Cape, these deposits grade into modern biogenic (shell) sands and, over the Blake Plateau, biogenic sandy-silt. Estuarine and other protected coastal areas are dominated by modern silts and clays. These fine-grained modern sediments also mantle the continental slope.

Geologic Occurrence of Fluid Hydrocarbons

Economically-attractive accumulations of oil and/or gas owe their existence to the proper interplay of three essential geologic elements. These are: a) source beds-rock strata which supply the

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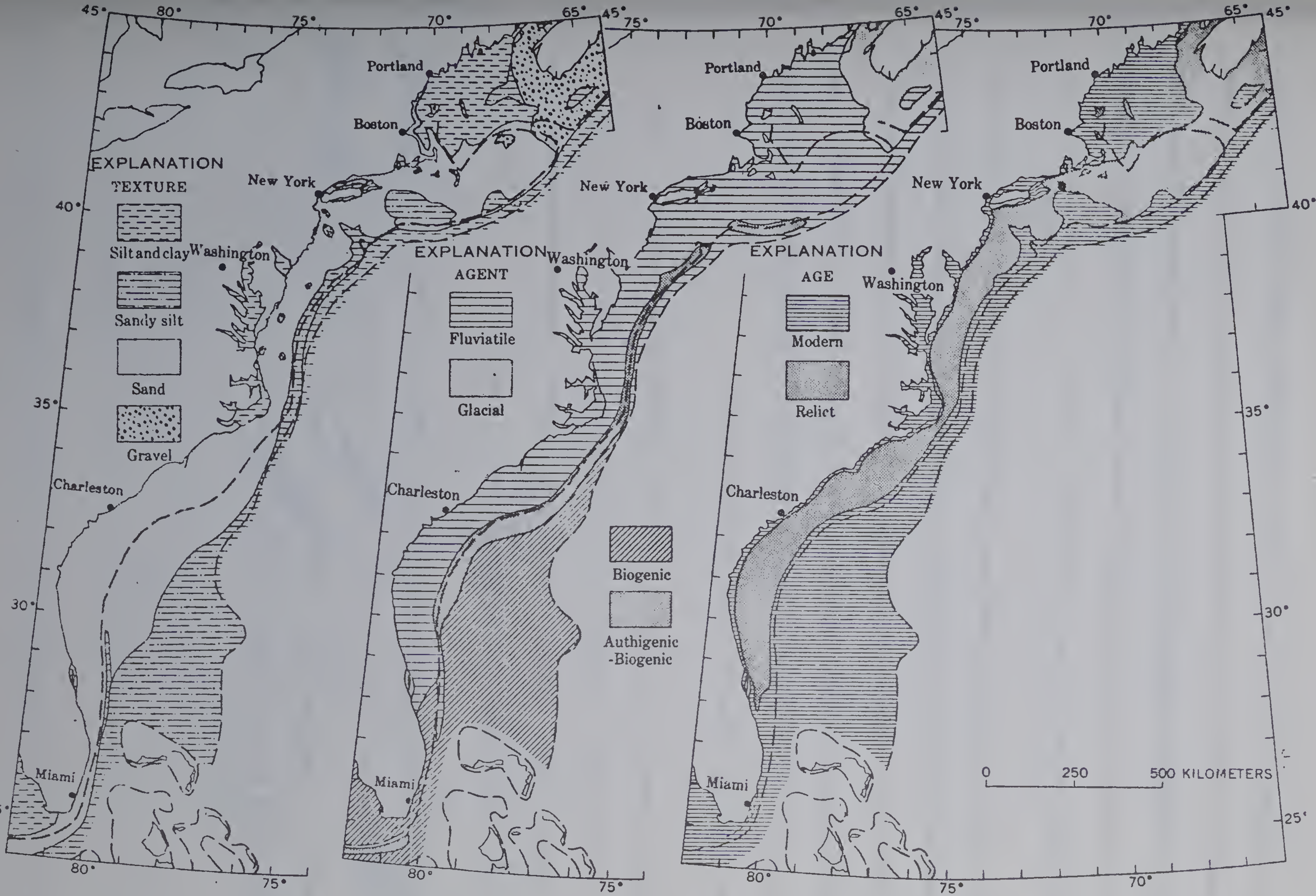


FIGURE 4 -Sediments off the Atlantic coast of the United States classified by texture, contributing agent, and age. The charts are based upon inspection of about 1,600 samples prior to detailed laboratory analyses. (from Emery, 1966).

organic material that is eventually transformed into fluid hydrocarbon; b) reservoir beds--porous strata into which these hydrocarbons migrate; and c) a trapping mechanism--a structural or stratigraphic (compositional) barrier which interrupts further migration and allows significant hydrocarbon accumulations to develop.

Source beds for hydrocarbons are generally regarded to be marine shales, marls (calcareous clays) and limestones, in about that order of importance. Chemical processes involved in the conversion of organic debris in these rocks to oil and gas occur at extremely slow rates, and require initial conditions of quick burial such as those found in areas of rapid sedimentation.

Potential reservoir strata, generally sandstone or limestone, must be characterized by sufficient porosity and/or permeability, and be located close enough to the source beds to accommodate upward (buoyant) migration of the hydrocarbon fluids.

These fluids would continue to ascend the stratigraphic rock sequence if there was not some impervious barrier present to halt this movement. The favorable structural relation of permeable rock strata with an impermeable sealing bed is known as a 'trap'.

Traps for fluid hydrocarbons are broadly classified as either stratigraphic or structural, although many have elements of both these types. Figure 5 illustrates three of the more common traps; anticlinal and fault types are structural in nature, while the stratigraphic trap is compositional.

Fluid hydrocarbon accumulations are density-stratified; gas, if present as a separate phase, assumes the highest position in the trap while any water present, being more dense than both oil and gas, assumes the lowest. All these fluids exist under relatively high formation pressures due to the weight of overlying rock strata.

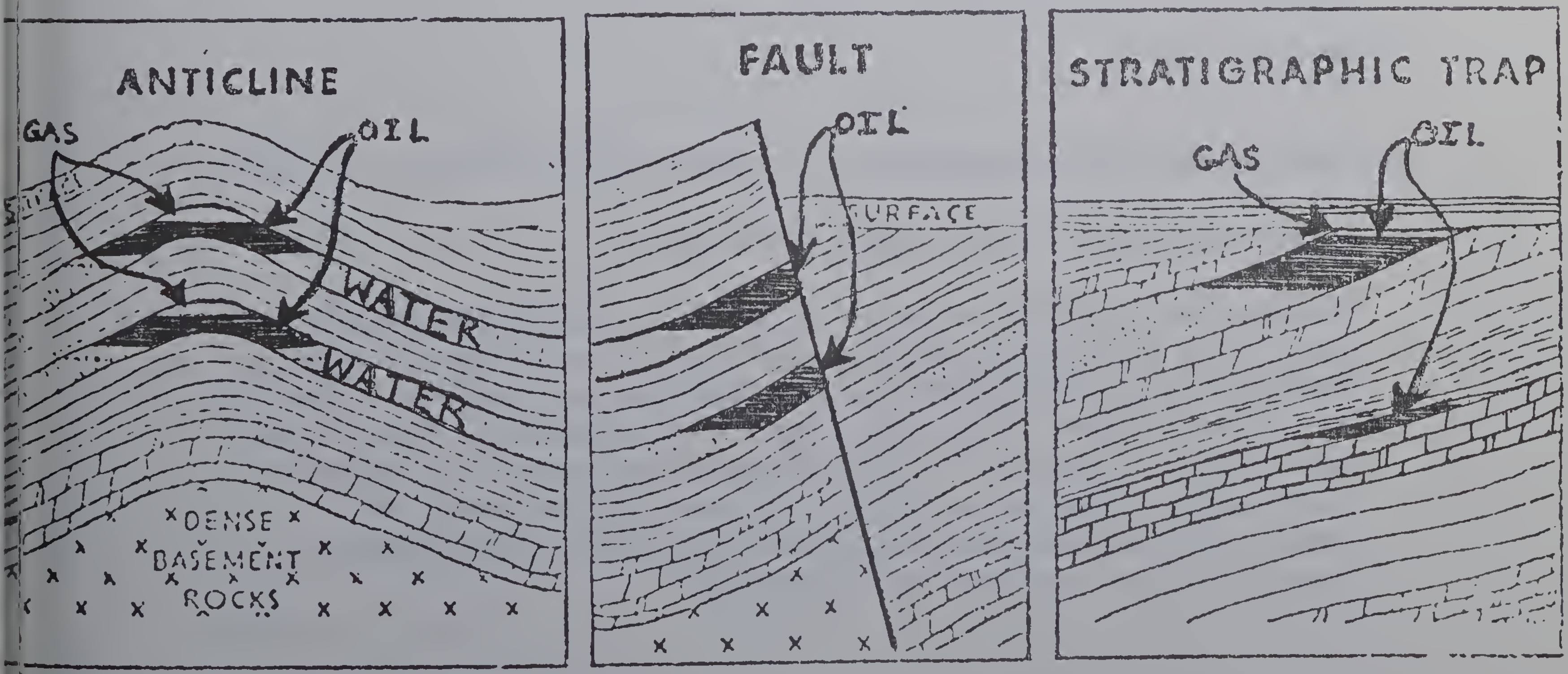


Fig. 5

(rom *Petroleum Discovery and Production*, pamphlet, American Petroleum Institute, New York, N.Y.)

Hydrocarbon Potential of the Atlantic OCS

The Atlantic OCS is essentially an untested region. Although a significant body of offshore geophysical data exists, actual sampling of the bottom strata has been mainly limited to scattered dredge hauls and shallow cores; a few test holes have been drilled into shelf areas off Georgia and Florida. Much of the inferred offshore stratigraphy beneath the shelf has been interpreted from onshore drill data obtained from widely-spaced wells scattered along the Atlantic coastal plain.

In the north Atlantic, on Canada's eastern continental shelf, drilling activity has occurred since 1965, with 54 wells drilled or were being drilled by the end of 1972 (Amoco Ltd. and Imperial Oil Ltd. Staffs, 1974). Information gained from these wells has been helpful in interpreting geophysical data from the northeastern United States continental shelf.

In summarizing unique aspects of the petroleum potential of the Atlantic OCS region, Rouse (1971) observed:

> "There is a general absence of evidence of rapid deposition and rapid burial of great quantities of sediments, as well as an absence of growth or contemporaneous faults of the type that formed structural and stratigraphical traps from which much of the prolific Gulf Coast oil and gas production comes. There is little evidence of Mesozoic or Cenozoic tectonic activity that would form structures of the type that produce in California."

Sedimentary rocks of the Atlantic OCS were deposited primarily in a transitional shallow-marine environment so that the present stratigraphic sequence probably contains a good mix of potential reservoir and source beds.

Favorable structures occur beneath many areas of the shelf, with many, such as those within the Georges Bank and Baltimore Canyon trough regions, representing possible structural traps. In southern areas of the Atlantic shelf and slope, hydrocarbon accumulations may occur in association with reef structures and stratigraphic traps resulting from the intermingling of carbonate, clastic and evaporite strata.

(1) North Atlantic OCS

(a) General

The North Atlantic continental shelf area includes several varied physiographic regions. The East Coast shelf, located to the south of Long Island is relatively featureless while further north, the floor of the Gulf of Maine has been severely altered by Quaternary glacial events. An anomalous extension of the East Coast shelf, Georges Bank, lies between these two physiographic regions and shares topographic characteristics with each. Several prominent submarine canyons dissect the continental slope of the North Atlantic region. Figure 6 shows the general physiography of the northeastern United States continental margin.

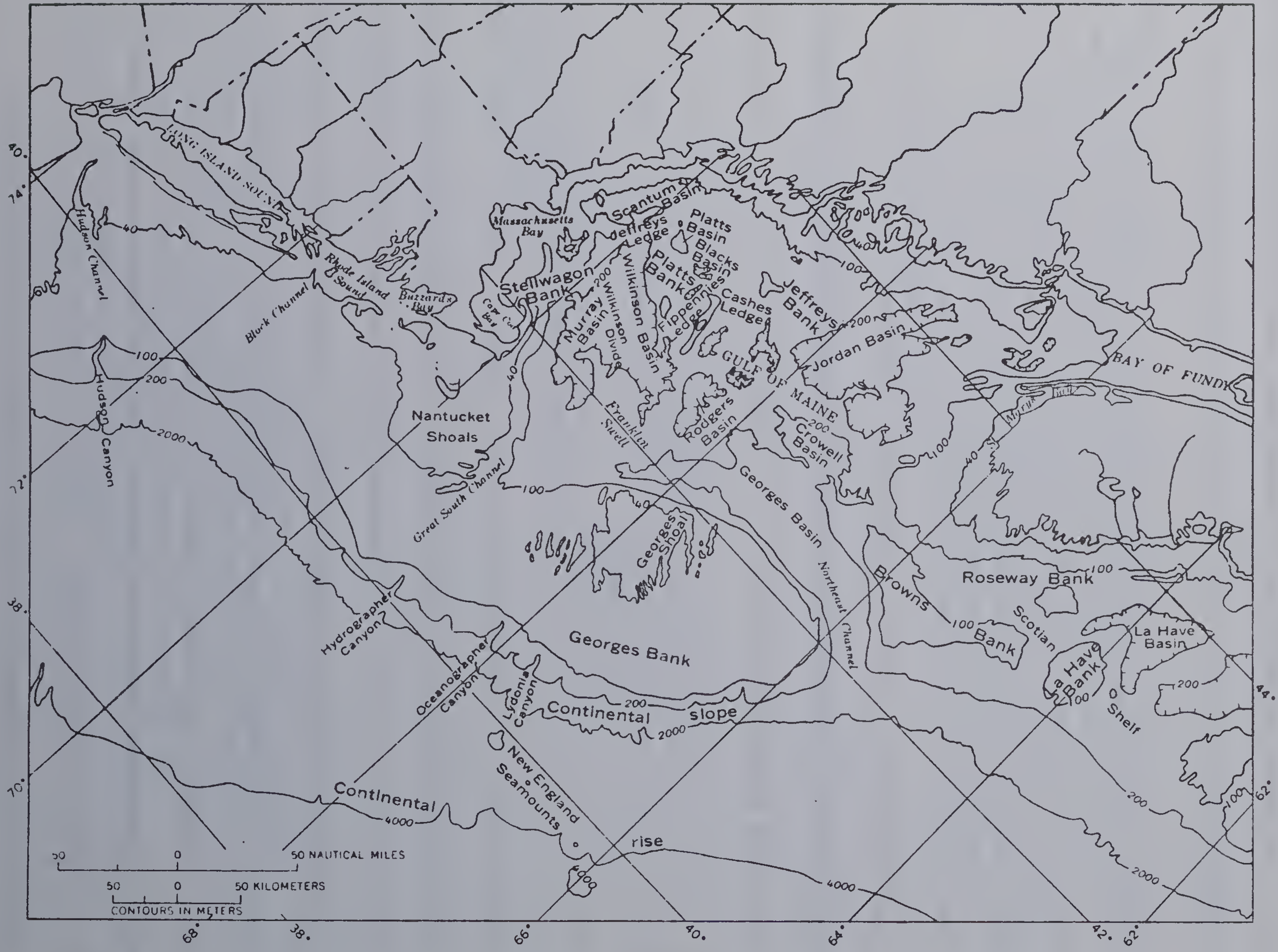


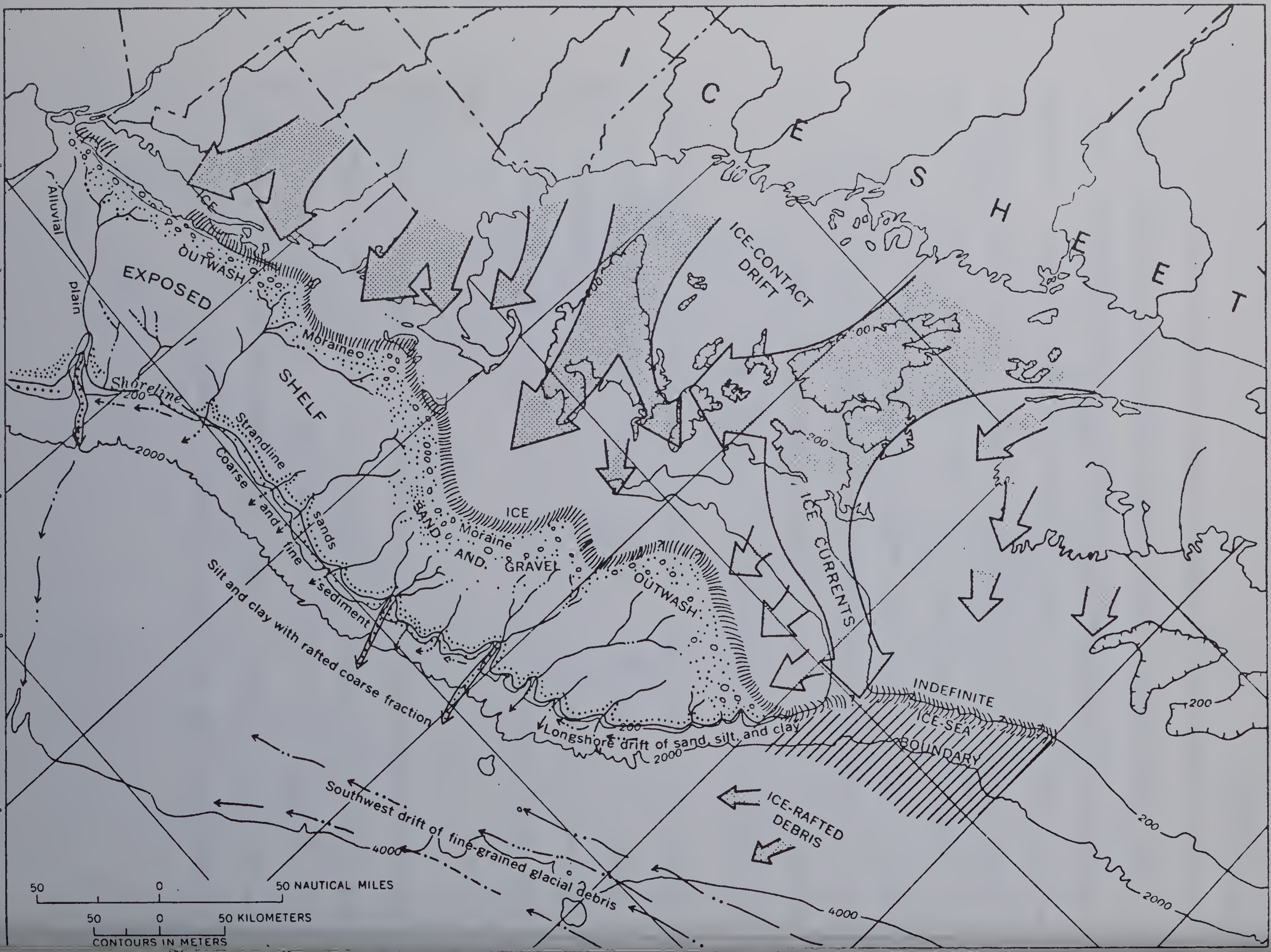
FIGURE 6.-Bathymetric map of the continental margin off the Northeastern United States. (from Schlee, 1973; after Uchupi, 1965).

Gulf of Maine

The Gulf of Maine is an elliptical basin, elongate toward the northeast and separated from the deep ocean proper by Georges Bank. The basin covers approximately 25,000 square miles (90,700 sq. km) and is submerged to an average water depth of 150 meters. Northeast Channel, located to the southeast, provides a deep water connection to the open sea. The floor of the Gulf is characterized by a complex series of fairly deep basins separated by low swells and flat-topped banks. Depths of the basin areas range generally from 100 to 300 meters while water depths over ridge crests vary from 40 to 80 meters. Ammen Rock, in the central Gulf, shoals at 9 meters.

Sediment cover in the Gulf of Maine varies broadly from sand and gravel on the topographic highs to silt and clay in the basins. Intermediate topographic areas show a diverse range of sediment grain size. Modern, fine-grained sediments occur along coastal areas.

The poorly-sorted (mixed grain size) relict sediments, irregular topography, and subsurface structure of the Gulf of Maine clearly reflect the glacial history of this region. Figure 7 shows the maximum extent of the last great ice advance in the northeastern United States and its effect on shelf sediment distribution.


ICE SHEET
ICE
OUTWASH
EXPOSED
Alluvial
plain
Moraine
SHELF
Shoreline
200
Strandline
Coarse
and
fine
sediment
sands
2000
ICE
Moraine
SAND AND GRAVEL
OUTWASH
ICE-CONTACT DRIFT
ICE CURRENTS
INDEFINITE ICE-SEA BOUNDARY
Silt and clay with rafted coarse fraction
Longshore drift of sand, silt, and clay
Southwest drift of fine-grained glacial debris
ICE-RAFTED DEBRIS
4000
40°
74°
72°
38°
70°
44°
62°
50
0
50 NAUTICAL MILES
50
0
50 KILOMETERS
CONTOURS IN METERS

[illegible]

East Coast Shelf

Although this province extends into the North Atlantic OCS region, the East Coast Continental Shelf is a more characteristic feature of the Central Atlantic region, and will be discussed as such in section II.A.1.a.(2).

Georges Bank

Georges Bank represents the southwesternmost of a series of banks on the continental shelf that parallel the western North Atlantic Coast between Newfoundland and Nantucket Island. This northeast-southwest trending bank measures approximately 150 km to 280 km, and serves as a barrier between the Gulf of Maine and the open sea. Georges Bank is isolated itself from the adjacent Scotian Shelf by Northeast Channel, and the East Coast Shelf by Great South Channel (see Fig.

Surface relief over the southern half of Georges Bank is relatively minor whereas, to the north along the crest of the bank, relief takes the form of a series of parallel, northwest-trending ridges and troughs. Superimposed on these ridges and troughs is a series of linear sand waves having various shapes and orientations (Fig. 8 Individual waves range in height from 10 to 20 meters and show considerable variation in length, from 200 meters to as much as 10 km (Uchupi, 1968). Sand waves atop some of the more prominent ridges appear to be migrating in response to bottom and tidal currents; Stewart and Jordan (1964) deduced at least a 300 meter westward shift in the sand wave regime on the crest of Georges Shoal.

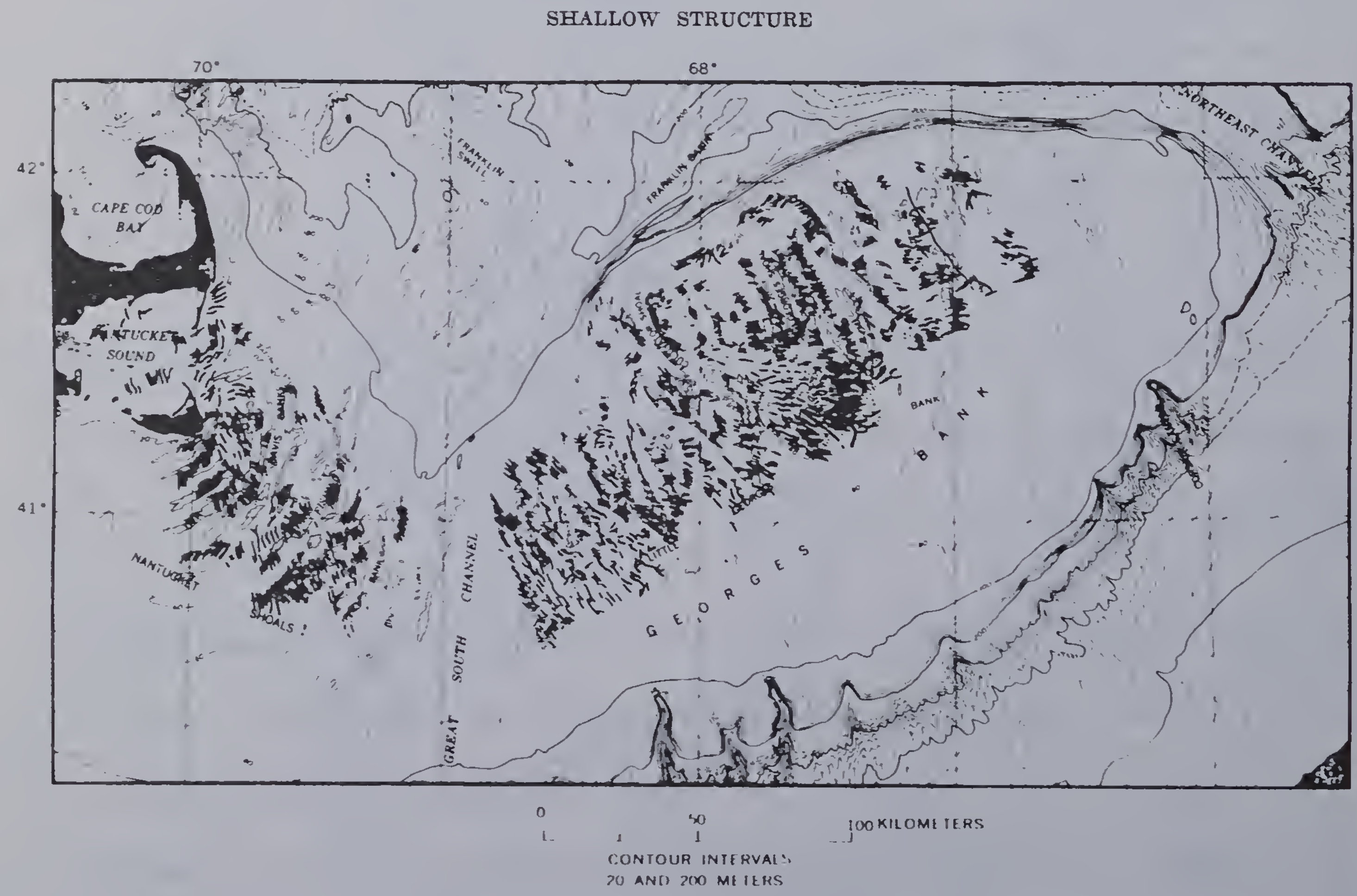


Figure 8. Distribution of sand ridges and swales on Nantucket Shoals and Georges Bank. From Uchupi (1970).

(b) Hydrocarbon Potential

The feature thought to have the greatest current hydrocarbon potential in the north Atlantic OCS region is the Georges Bank trough, an arcuate, northeast-southwest trending structural depression on the basement surface beneath Georges Bank. The trough is approximately 120 miles (193 km) long and up to 8 kilometers in depth. Figure 9 gives the general location and configuration (in depth to basement) of this structural feature.

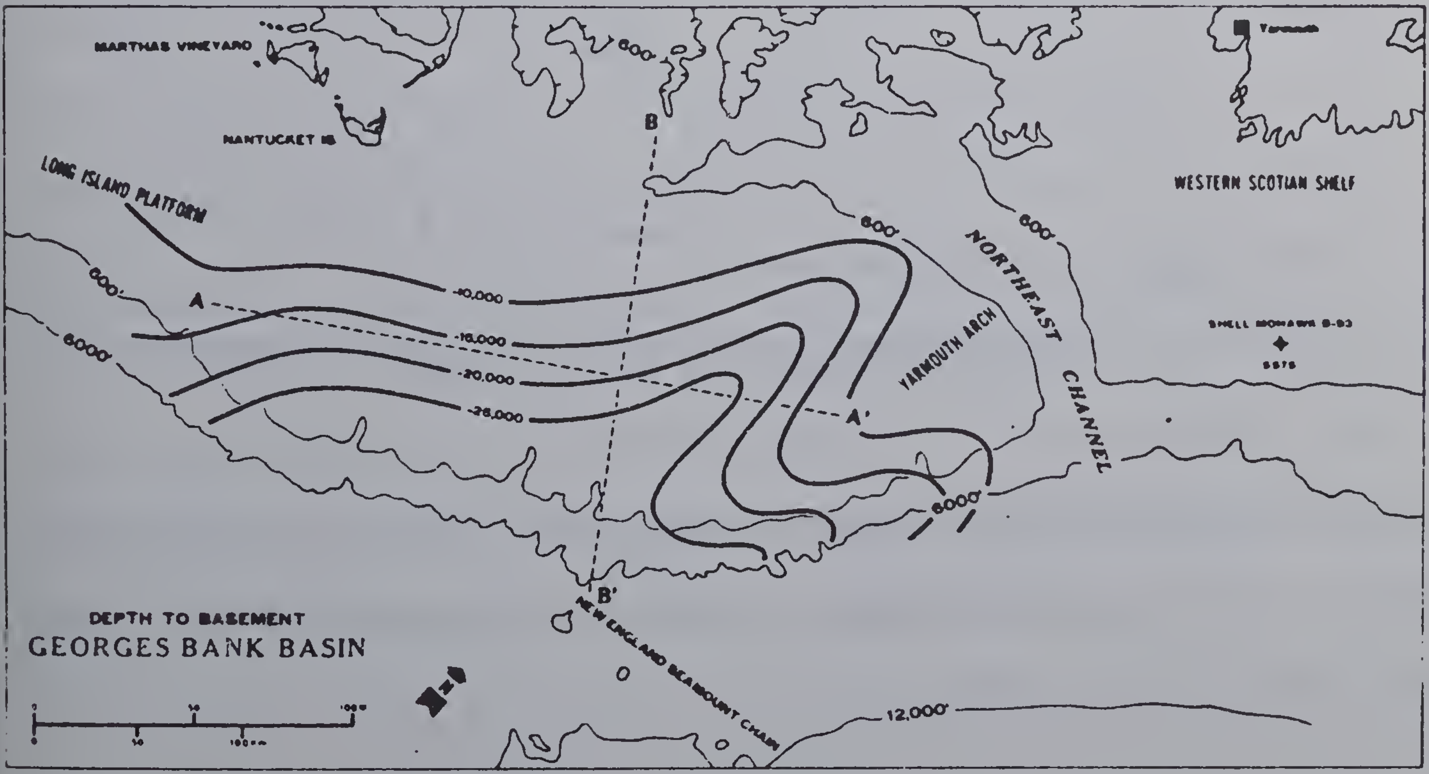


Fig. 9.-Generalized structure-contour map showing depth to pre-Mesozoic basement. Contour interval 5,000 ft. Based on Maher (1965) and other published data.
(from Schultz and Grover, 1974).

Seismic data and information from wells drilled into the adjacent western Scotian shelf suggest the presence of up to 14,000 feet of Lower Cretaceous and earlier Mesozoic carbonate, marine shale, evaporites and sandstone overlain by as much as 12,000 feet of Upper Cretaceous and Tertiary sandstone and shale (Schultz and Grover, 1974). A generalized northwest-southeast cross-section through the Georges Bank trough is shown in Fig.10.

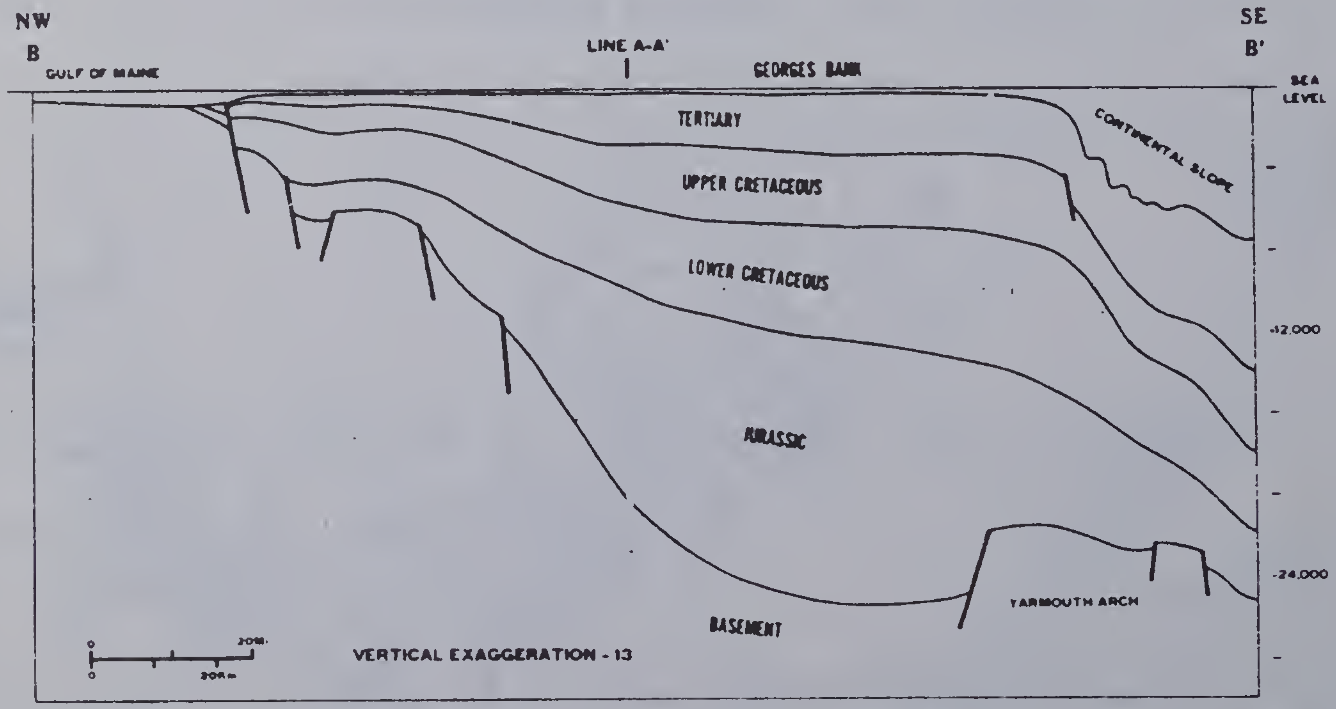


Fig. 10 Dip section of Georges Bank basin. Normal to coastline and shelf edge. Vertical exaggeration 13 to 1. (from Schultz and Grover, 1974).

Although Jurassic strata beneath Georges Bank may contain evaporites, diapiric salt structures similar to those found beneath the Scotian shelf have not been detected.

Extensive high-angle basement faulting appears to have affected only the lower several thousand feet of sediment. The Yarmouth arch, a basement feature that borders the trough on the southeast, appears to have been fault-controlled.

Elsewhere in the north Atlantic region, Emery (1965) suggested that favorable hydrocarbon-bearing structures may be associated with the basement ridge at the edge of the shelf, and a major fault inferred from geophysical data to extend just southeast of New York City.

(c) Geologic Hazards

The eastern coast of the United States is generally considered to be aseismic or relatively free from major earthquake occurrence. In 1755, however, a major earthquake occurred at Cape Ann, Massachusetts. This quake was rated at an intensity of VIII on the modified Mercalli-scale (Wood and Newmann, 1931)--a subjective scale of earthquake intensity based on observable effects (Table 14). Because of this earthquake, the coastal areas of Massachusetts and New Hampshire are placed in Zone 3 of NOAA's Seismic Risk Map (Algermissen, 1969) (Fig. 11 where major destructive earthquakes may occur. The southern coast of Maine lies in Zone 2, while the northern Maine coast falls in Zone 1, where only minor damage can be expected.

Table 14.

MODIFIED MERCALLI INTENSITY SCALE OF 1931[1]

(ABRIDGED)

I. Not felt except by a very few under especially favorable circumstances. (I Rossi-Forel Scale.)

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing. (I to III Rossi-Forel Scale.)

III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing truck. Duration estimated. (III Rossi-Forel Scale.)

IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, and doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably. (IV to V Rossi-Forel Scale.)

V. Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop. (V to VI Rossi-Forel Scale.)

VI. Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight. (VI to VII Rossi-Forel Scale.)

VII. Everybody runs outdoors. Damage *negligible* in buildings of good design and construction; *slight to moderate* in well built ordinary structures; *considerable* in poorly built or badly designed structures. Some chimneys broken. Noticed by persons driving motorcars. (VIII− Rossi-Forel Scale.)

VIII. Damage *slight* in specially designed structures; *considerable* in ordinary substantial buildings, with partial collapse; *great* in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motorcars disturbed. (VIII+ to IX Rossi-Forel Scale.)

IX. Damage *considerable* in specially designed structures; well-designed frame structures thrown out of plumb; *great* in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken. (IX+ Rossi-Forel Scale.)

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks. (X Rossi-Forel Scale.)

XI. Few, if any (masonry), structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII. Damage *total*. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.

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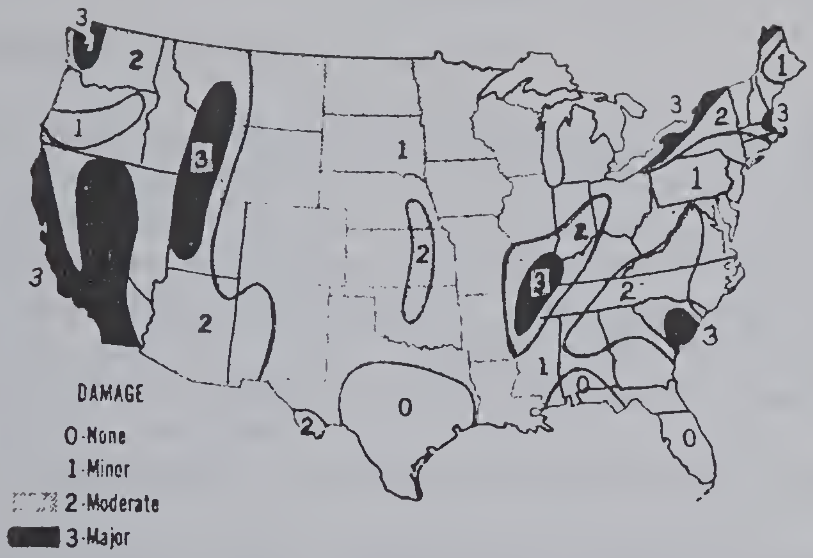
[1] Harry O. Wood and Frank Neumann, in *Bulletin of the Seismological Society of America*, Vol. 21, No. 4, December 1931.

Figure 11.



Seismic risk map for conterminous United States.
(from Algermissen, 1969).

Although the Cape Ann earthquake occurred along a northwest-southeast trending zone of activity that, when projected to the southwest, crosses the central portion of Georges Bank, the absence of recorded activity in this region suggests that no offshore seismic hazard exists.

Other geologic hazards involve the irregular topography, relatively thick cover of unconsolidated sediments, occasional presence of boulders, and shifting surface sediments caused by the unusual bottom current regime. All these factors will have to be considered prior to rig and pipeline placements.

(2) Mid-Atlantic OCS

(a) General

The mid-Atlantic OCS region has been arbitrarily defined as that portion of the East Coast continental margin which lies between 35°N and 40°N latitudes. Within this area, the continental shelf varies in width from 85 miles (140 km) off New Jersey to as little as 15 miles (25 km) off Cape Hatteras. Shelf declivities range from 0°04' in the northern area to 0°07' off the narrow southern zone while the shelf break occurs at water depths of about 140 meters off central New Jersey but only 55 meters off Cape Hatteras.

The East Coast shelf displays a great variety of morphologic features. Uchupi (1968) classified these as either erosional features such as channels and terraces, or depositional forms, e.g. ripples and sand waves. The erosional features are generally relict, dating from extended periods of lowered sea level that characterized the later stages of the Pleistocene Epoch. Many of the relict stream channels are now filled with sediment.

The sand ridges occur in water depths generally less than 30 meters. Many of the nearshore ridges have been historically active, migrating over considerable distances in response to storm-generated currents and intense wave activity. Further offshore, the ridges and swales are probably relict features modified somewhat by modern tidal and storm activity.

Figure 12 shows the general distribution of former shoreline terraces, submerged river valleys and submarine canyons that characterize the mid-Atlantic OCS region, while Fig.13 depicts the extensive occurrence of linear sand ridges and swales.

Coastal Features

Embayed estuaries and barrier islands are the dominant coastal features of the mid-Atlantic region. Delaware and Chesapeake Bays are the largest estuaries on the East Coast and represent drowned river channels dating from the Pleistocene. Although these bays drain an extensive land area, suspended sediment input is comparatively less than that discharged into more southern coastal embayments. This difference reflects the effective removal of much of the erodable sedimentary cover from northern land areas by past glacial activity. Much of the sediment discharged by coastal rivers of the mid-Atlantic region is retained within estuarine areas; at present, sedimentation rates within these features range between 15 and 40 cm per century (Milliman, 1973).

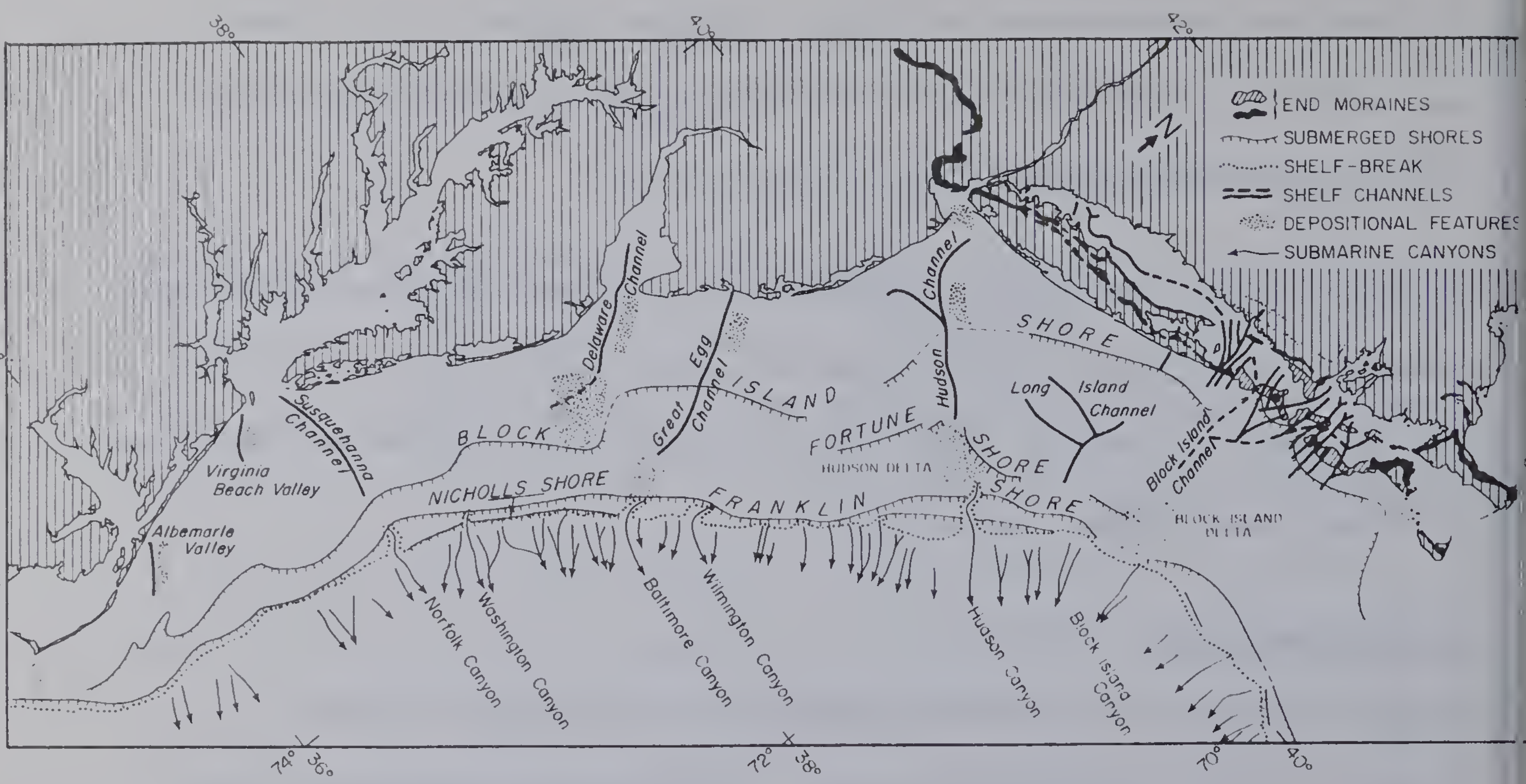


Figure 12. . Schematic chart of the various morphologic features on the continental shelf (excluding sand ridges and swales) and upper slope. Dashed shelf channels are filled with sediment. (from Milliman, 1973

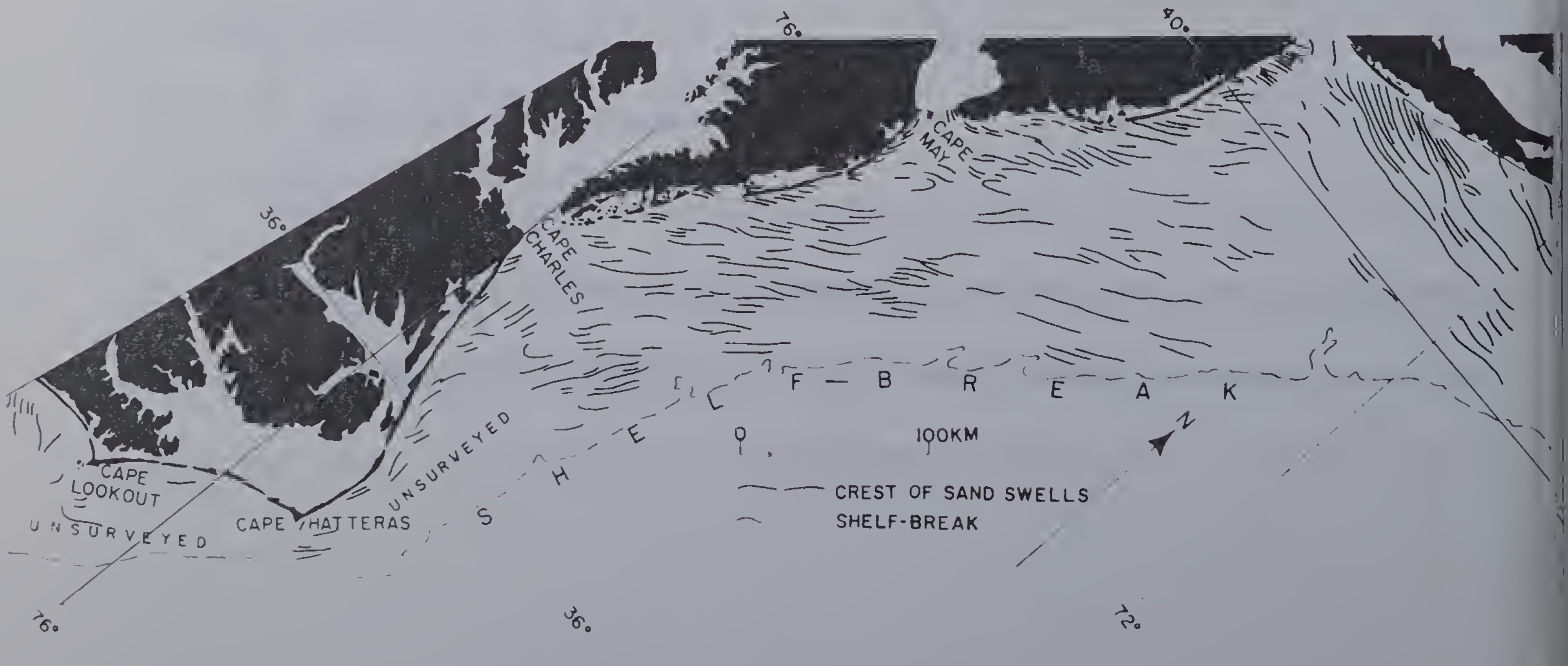


Figure 13. . Sand ridges and swales on the shelf between Long Island and Cape Hatteras(from Milliman, 1973; after Uchupi, 1968).

Barrier islands form a more or less continuous chain stretching from western Long Island to Cape Hatteras. The islands are generally long and thin (<1 km) with elevations usually less than 4 meters; local dune elevations may exceed 10 meters. Composed primarily of sand, these islands may have been formed either during the Holocene transgression (rise in sea level) or, as a result of longshore drift and seaward progradation over the shelf. Seasonal storm activity commonly causes cyclic migration in the relative shoreline position of these barrier islands, with little apparent net change over a complete cycle. Modern barrier spits associated with many of the islands appear, however, to be migrating along the shoreline as well as eroding landward.

Structure

The structure of the mid-Atlantic OCS region represents essentially a southward continuation of trends evident in the northern Atlantic region beneath Georges Bank. The section thickens considerably offshore southern New Jersey where Mattick et al. (1974) estimate about 12 km of undeformed post-Jurassic and Jurassic sedimentary rocks fill the Baltimore Canyon trough. Additional thicknesses of Triassic strata may be present at the base of the trough, however, sedimentary rock densities at this depth would approximate those of the crystalline basement, making geophysical delineation of these strata highly speculative.

The previously-mentioned basement ridge that borders the Baltimore Canyon trough on the east, lies at a depth of 10 km in this region. Figure 14 represents a generalized cross-section off Island Beach, New Jersey (about 40°N lat.) while Fig. 15 shows a thicker southern section through the Baltimore Canyon trough area.

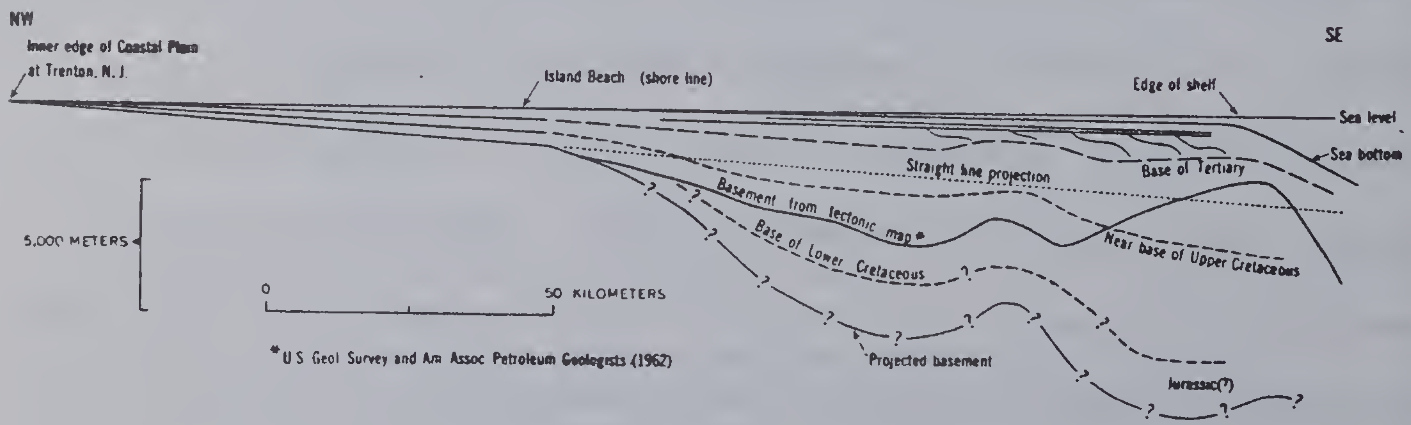

NW
Inner edge of Coastal Plain at Trenton, N. J.
Island Beach (shore line)
SE
Edge of shelf
Sea level
Sea bottom
Straight line projection
Base of Tertiary
Basement from tectonic map*
Near base of Upper Cretaceous
Base of Lower Cretaceous
5,000 METERS
0
50 KILOMETERS
*U S Geol Survey and Am Assoc Petroleum Geologists (1962)
Projected basement
Jurassic(?)
?

FIG. 4—Diagrammatic cross section of continental margin units in and adjacent to New Jersey; (from Minard, et al., 1974).

(b) Hydrocarbon Potential

Much of the future petroleum potential of the mid-Atlantic OCS region is related to the thick Mesozoic and Cenozoic sediment accumulation that fills the Baltimore Canyon trough. Stratigraphic interpretation of these sediments is based primarily on the correlation of offshore geophysical data with onshore well data. These correlations suggest that Jurassic strata may be as much as 15,000 feet thick, and may contain significant amounts of carbonates and evaporites. Cretaceous sediment

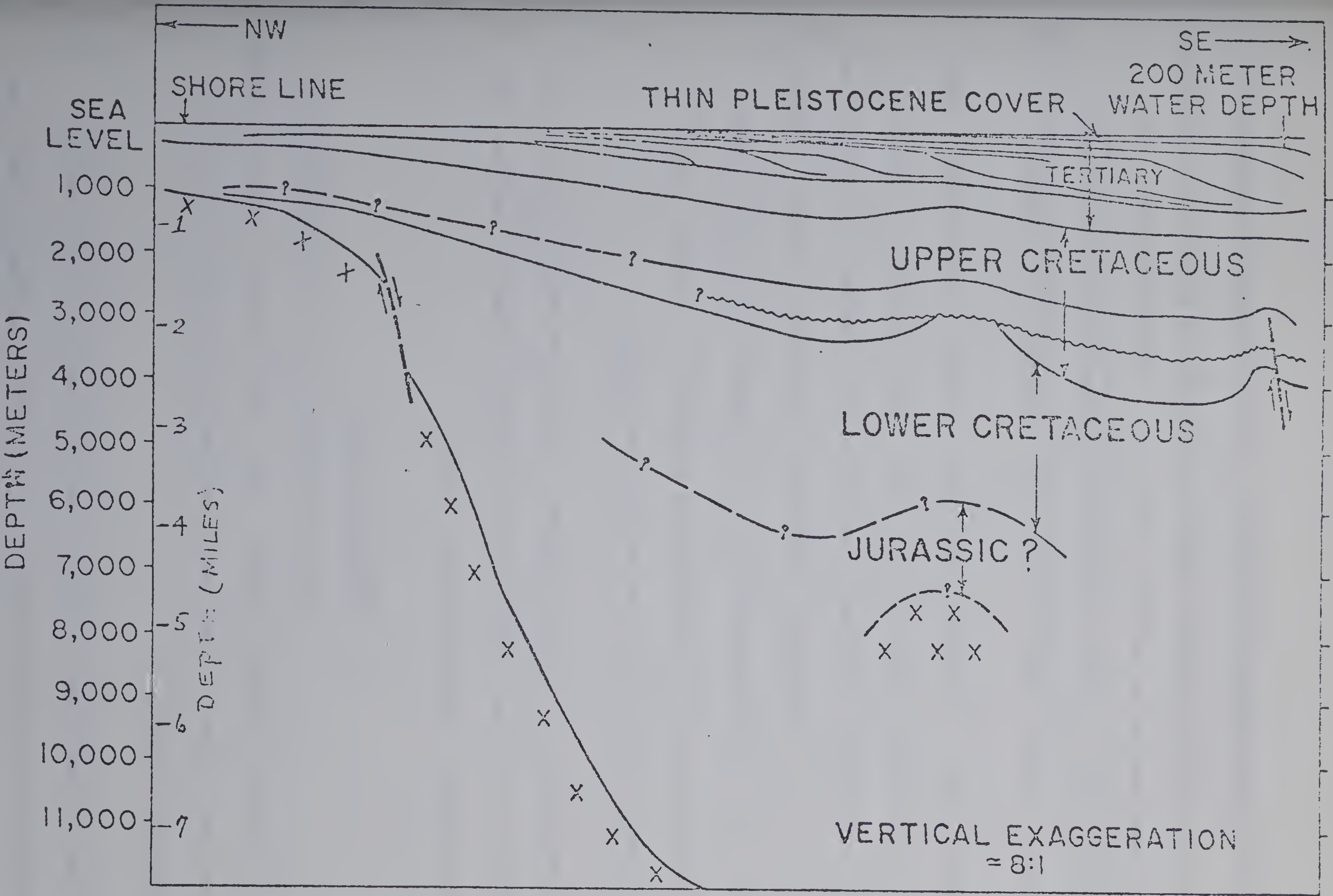


Figure 15.--A composite, diagrammatic cross section through Baltimore Canyon trough illustrating potential petroleum entrapment features.

Source: R.E. Mattick, AND [illegible]

thickness may approach 20,000 feet, while the overlying Tertiary section probably does not exceed 6,000 feet in thickness. Onshore well data suggest a general tendency for Lower Cretaceous and Jurassic strata to thin considerably, westwards and become more clastic in nature, thus forming good stratigraphic trapping potential.

Several types of potential petroleum entrapment features may exist in the Baltimore Canyon trough area. These include: anticlinal traps associated with deep-seated intrusive bodies, reef traps and pinchouts of stratigraphic units against buried erosional surfaces, and fault traps associated with the basement ridge to the east. In addition, gravity measurements suggest the possible presence of diapiric salt structures within the trough.

On the negative side, high seismic velocities shown by the older Mesozoic strata may indicate that potential reservoir strata have low porosities (Mattick, et al., 1974).

(c) Geologic Hazards

The mid-Atlantic OCS is characterized by few potential geologic hazards. The coastal region lies in seismic risk Zone 1, and is thus characterized by only minor risk of earthquake damage.

The most significant potential geologic hazard in this region concerns the transient nature of inner shelf sediments; both the linear ridges and nearshore barrier islands are susceptible to pronounced morphologic change during severe storm activity.

Of additional concern are the moderate relief, random distribution, and unconsolidated character of these sedimentary features.

(3) South Atlantic OCS

(a) General

The East Coast continental margin south of Cape Hatteras represents a unique and complex assemblage of varied physiographic features. The East Coast shelf widens southward from 23 km off Cape Hatteras to 132 km at latitude 31°, then narrows again to about 3 km off West Palm Beach, Florida. South of Cape Lookout, the shelf is flanked by the Florida-Hatteras slope, a relatively smooth incline that drops off from a few meters in the north to more than 700 meters in the south, onto the Blake Plateau.

Blake Plateau

The Blake Plateau is a broad platform that ranges in depth from 60 to 750 meters along the western margin and from 800 to 1000 meters along its seaward edge where it is flanked by a segment of the continental slope known as the Blake Escarpment. The plateau is separated from the Bahama Banks to the south by a smooth 800 meter-high slope.

The surface of Blake Plateau is narrow and relatively steep in the northern region, but widens and flattens out toward the south. The southern area of the plateau consists of a series of broad benches (Fig. 16) separated by 100-200 meter-high slopes, and is marked by numerous coral mounds, some up to several hundred feet high.

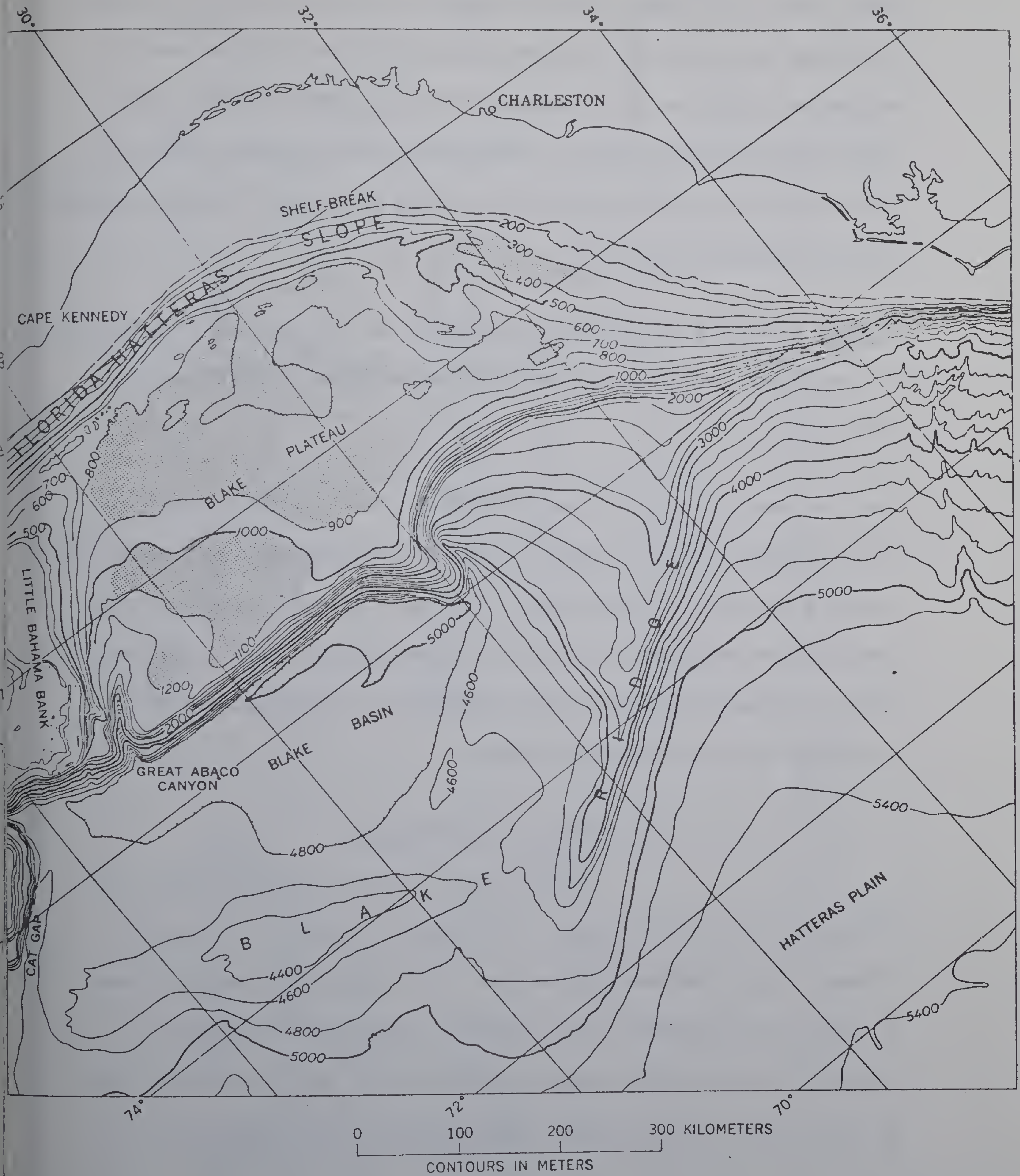


Figure 16.-Bathymetry of the Blake Plateau (modified from Pratt, 1967). Shaded areas are benches. (from Uchupi, 1968).

Ewing, Ewing and Leyden (1966) regard the Blake Plateau as a slowly subsiding segment of an ancient continental shelf whose eastern margin was supported by a basement arch and which subsided more slowly than the other parts. Carbonates were deposited over the plateau, with greatest accumulation taking place over the more rapidly subsiding western part.

Seismic profiling has revealed that most of the surface irregularities on the Blake Plateau have resulted from erosive activity of the Gulf Stream.

The continental slope off Cape Hatteras is cut by numerous gullies which coalesce near its base to form the Hatteras Canyon. From this region southward to Blake Spur, the slope descends from a depth of about 1000 meters, onto the crest of Blake Ridge. South of Blake Spur, the Blake Escarpment drops rapidly at an average gradient exceeding 20° into the Blake Basin.

(b) Hydrocarbon Potential

The Southeast Georgia Embayment area is a downwarped continental margin geosyncline filled with Jurassic through recent sediments deposited in a seaward-thickening prism. Faulting may be present but currently, patterns are unknown. Seismic refraction data suggests the presence of a basement ridge or fault block near the shelf/slope margin. As shown in Fig. 17

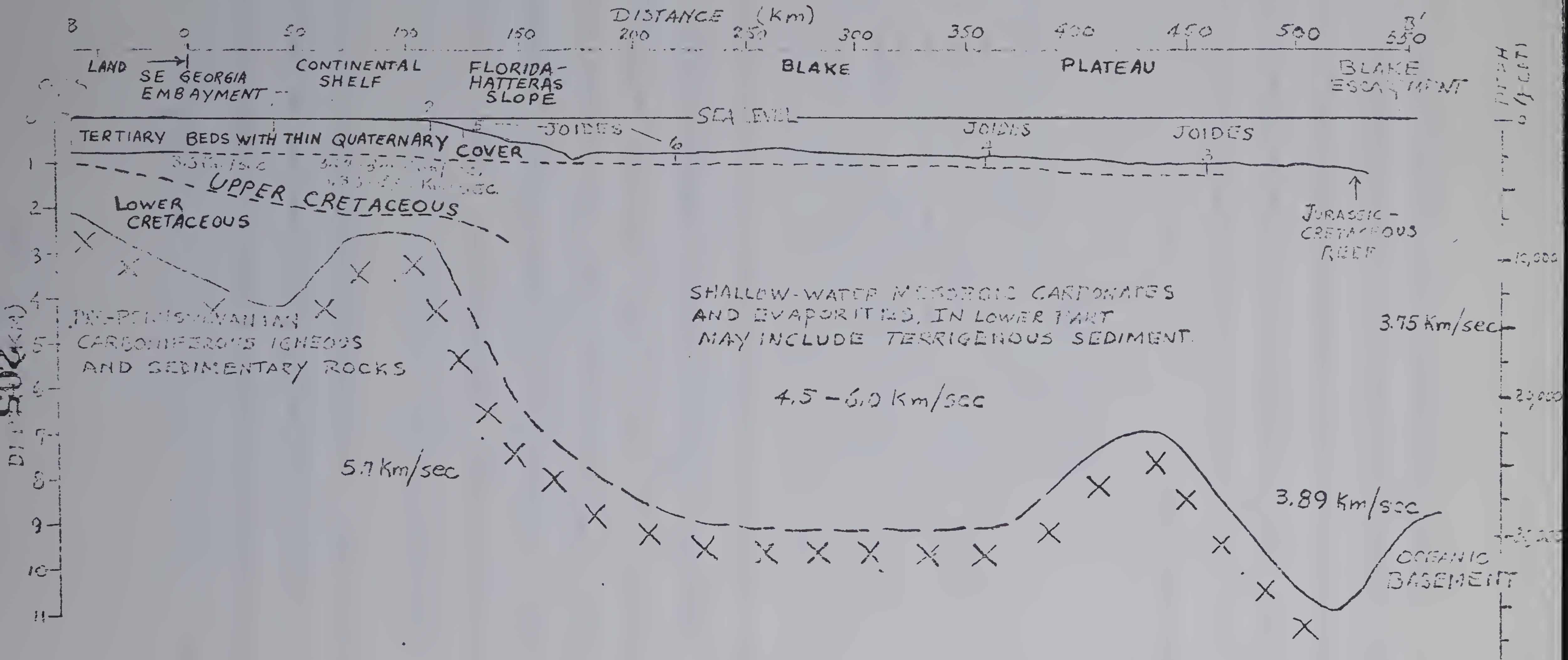


Figure 17. CROSS SECTION ACROSS SOUTHEAST GEORGIA EMBAYMENT AND BLAKE PLATEAU

SOURCES:
J.C. MAHER, 1971, FIG. 8, P. 43;
K.O. EMERY AND E. UCHUPI, 1972, FIG. 94, P. 162.

this area is contiguous with a much deeper trough under the adjacent Blake Plateau. Both areas are probably chiefly underlain by Cretaceous carbonate and clastic sediments. The source area of the probable clastic suite of sediments lies to the west and northwest. In general, very little is known about this basin as far as petroleum potential and structure.

(c) Geologic Hazards

The extensive distribution of sand waves that characterize the inner shelf surface of the north and central Atlantic regions extends also over the southern shelf area. The discussion of potential hazards related to shifting sediments in these other areas would apply equally to the south Atlantic region.

Various parts of the south Atlantic coastal region are characterized by seismic risk values from 0 (central and southern Florida) to 3 (South Carolina). The South Carolina designation resulted primarily from a Modified Mercalli 1X-X seismic event that occurred in 1886 near Charleston. Several other less severe (V-V11) earthquakes have occured along the South Atlantic coast, primarily in South Carolina (Department of Commerce, 1973).

Since most drilling on the Blake Plateau would have to be done in water depths exceeding 600 meters, this area does not have as high an economic appeal as potential areas of the more northern Atlantic OCS.

b. Climate of the Atlantic Coastal Area

(1) General Climatology and Seasonal Weather Patterns

The position and intensity of the Bermuda-Azores high pressure system for the most part, controls the general surface weather patterns along the Atlantic coast. Major low pressure systems usually move in a north to northeast direction through the area. These storms occur most frequently during the winter season when the Bermuda-Azores high is far to the southeast, and may persist in an area for several days, generating high winds and sea states. The polar front, marked by a horizontal thermal gradient in the trophosphere, commonly provides energy for storm development and maintenance, and separates air masses of polar and tropical origin (Edinger, 1967). The most severe storm systems occurring in the Atlantic area are classified as hurricanes, which bring abnormally high storm tides and seas simultaneously. Eighty percent of the hurricanes occurring between 1886 and 1972 occurred between August and October. A study prepared for the Council on Environmental Quality by Tetratech presents annual probabilities of winds exceeding various speeds. The probability of winds exceeding 80 knots would be 0.05/year and 100 knots would be 0.01/year.

The climate of the region from Cape Hatteras to Cape Canaveral is mild and maritime (cool moisture-laden sea breezes,.moderate summer and winter temperature systems). Average winter temperatures average from 45°F. at Cape Hatteras to 60°F. at Cape Canaveral.

The average annual number of days with a minimum temperature below 32°F. is 25 at Wilmington, North Carolina in the north to 2 at Cape Canaveral, with less than 20 freeze days at Cape Hatteras. Autumn freezes begin as early as November 20 in Wilmington, and as early as December 20 north of Cape Canaveral.

Average summer temperatures for the entire region range from 78.5°F. at Cape Hatteras to 81.5°F. at Cape Canaveral. The number of days that the temperature exeeds 90°F. can be expected to range from 5 at Cape Hatteras to over 30 for the region extending just north of Wilmington, North Carolina to Cape Canaveral (VIMS, 1974).

The moderate summer temperatures in the Cape Hatteras region are attributed to the proximity of the cooler Virginia coastal water mass between the coast and the western edge of the Gulf Stream. Sea breezes further moderate summer temperatures with breezes blowing onshore during the day and offshore at night.

The middle Atlantic region from Cape Hatteras to Sandy Hook, New Jersey experiences latitudinal effects with annual average temperatures approximately 8°F. warmer at Norfolk, Virginia than at Quonset, Rhode Island. Seasonal averages range from 38°F. at Quonset and 46°F. at Norfolk in winter to 68°F. at Quonset and 76°F. at Norfolk in summer. Sea breezes again moderate onshore conditions, providing a mechanism for warming the coast during cooler months and cooling the coast during the warmer months (URI, 1974).

The North Atlantic area between Sandy Hook, New Jersey and the Bay of Fundy, Nova Scotia is a region best characterized by rapid weather changes. This area lies in the global zone of westerly winds (the westerlies) in the general path of tropical air masses moving from the Gulf of Mexico. The Appalachian Mountains west of the coast and the Atlantic Ocean have profound effects upon the climatology of the area. The interaction between the northward moving warm air masses and the eastward moving continental air masses is conducive to rapid meteorological changes (TRIGOM, 1974).

During the winter, onshore winds tend to maintain higher temperatures along the coast. During the summer this same mechanism exists to cool the coastal areas due to differences in the rate of cooling of water and land.

Average annual temperatures in the area vary from approximately 40°F. in northern Maine to 50°F. in southern New York Bight. New York City has an annual 54.5°F. mean, a 74.4°F. summer mean, and a 33.8°F. winter mean. Northern winters are severe and prolonged, with growing seasons averaging less than 100 days in some areas. The growing seasons may extend to 200 frost-free days in the southern part of the region (TRIGOM, 1974).

(2) Sky Cover and Visibility

Reduced visibility, caused by snow, heavy rainfall or fog is a major factor in the safety of operations. Sky cover (cloudiness) in the Atlantic is discussed following these topics.

Heavy fog ranges at land stations between Cape Hatteras and Cape Canaveral from an average of 6 days in January at Daytona Beach to less than one day per month at Cape Hatteras during July and September. Savanah reports heavy fog an average of 44 days a year. Fog occurs with much less frequency offshore of the southern Atlantic coast. Two percent of the offshore meteorological observations reported average visibilities of 5 miles or less in the southern Atlantic area throughout the year to at least 3% off Cape Hatteras from January through March and again in June. This areas averages visibilities less than 5 miles occur in excess of 2% of the time except in July. These visibility records do not indicate the particular causal factors but are a total of the effects of haze, fog, high relative humidity and precipitation.

The northern portion of the Central Atlantic region has reduced visibility more often than the central or southern States within this region. Fog and haze in the three northern reporting stations (i.e. Quonset, New York, and Atlantic City) reduce visibility to less than 2 nautical miles 25% of the time during May, June, and July. Quonset reports average visibilities to be less than 0.5 nautical miles 13% of the month of June.

Boston has a higher frequency of reduced visibility (less than 2 nautical miles) than does any other area in the North Atlantic region. Reduced visibility is reported 15% of the time in July in Boston with the maximum occurrence of fog and haze in late spring and summer. During July, Boston reports significant fog or haze in 31.5% of the observations, with New York and Quonset reporting fog occurrences of 20%. Snowfall is mainly latitude related and can cause significant visibility reductions locally throughout the winter months in the North Atlantic region. Approximately 24% of all meteorological observations in Boston during February indicated rain or snow (URI, 1974).

Sky Cover

The average annual sky cover for the Atlantic Coast ranges from slightly over five-tenths at Miami to slightly less than six-tenths in the Gulf of Maine on a scale from 0 to 1.00. There is little seasonal variation at each reporting station but generally in the South Atlantic and North Atlantic regions, the summer months give higher values than the rest of the year (0.1 to 0.2 higher). Winter and late fall are the seasons of maximum cloudiness in the Central Atlantic region (U.S. Dept. of Commerce, 1968).

(3) Surface Wind Patterns

The general wind pattern along the Atlantic coast is strongly influenced by the position and intensity of the Bermuda-Azores High pressure system.

Summer winds along the Atlantic coast are generally from the southwest at 8 to 12 knots. Several exceptions include: average speeds of 13 knots at the Delaware Peninsula and Cape Cod, and predominantly easterly winds south of Cape Canaveral.

The winter pattern for Atlantic Coast surface winds is more complex. Winds south of Cape Canaveral are predominantly from the southeast at 10 knots. The prevailing winter winds from Cape Canaveral to the Georgia-South Carolina border are southwesterly at 10 knots. The predominant winter winds from the South Carolina-Georgia border north to Delaware Bay are northeasterly at 9 to 15 knots. From the Delaware Bay north to the Bay of Fundy, the average surface winds are from the northwest at 10 to 20 knots (U.S. Dept. of Commerce, 1968). These patterns reflect average conditions and do not represent local storm conditions.

(4) Air Temperatures

Average (1931 to 1960) monthly air temperatures for the United States were plotted by U.S. Dept. of Commerce (1968) and are discussed below. Temperature differences based on latitude are distinctive along the Atlantic coast. Winter average temperatures range from 70°F. at Key West to approximately 20°F. in the northern portion of the Gulf of Maine. Average winter latitudinal effects indicate a loss of 10°F. from 25°N to 30°N, 12°F. from

30°N to 35°N, 15°F. for 35°N to 40°N, and 12°F from 40°N to 45°N. Average daily ranges in temperatures are consistently between 15°F. and 20°F. along the entire Atlantic coast.

Coastal summer average temperatures range from 82°F. at Key West to 65°F. in the northern portion of the Gulf of Maine. Latitudinal effect on coastal summer temperatures is not as significant as in winter. Temperatures are essentially the same from 25°N to 35°N. A 5°F. drop in surface air temperatures is experienced from 35°N to 40°N, and 10°F. from 40°N to 45°N.

(5) Precipitation

Average total annual precipitation along the Atlantic coast ranges from a high of 59 inches in southern Florida to a low of slightly over 42 inches along the coast between Delaware Bay and Long Island. The values range from 43 to 45 inches for most of the coastline with the following exceptions; central and northern Florida averages 52 inches, North Carolina 48 to 50 inches, and the Long Island area 47.5 inches (U.S. Dept. of Commerce, 1968). These averages were computed based upon data from 1931 to 1955.

Most of the rainfall in the South Atlantic region occurs during summer thunderstorm activity. Hail frequently occurs during severe thunderstorms. Cape Hatteras also experiences a rainy season in late fall and winter as a result of persistent coastal storms (VIMS, 1974).

Snow occurs rarely in the southern portion of the South Atlantic region, and averages less than two inches per year in the Cape Hatteras area (U.S. Dept. of Commerce, 1968). Precipitation for the Central and North Atlantic regions occurs fairly evenly throughout the year. The fall season tends to be slightly wetter than the rest of the year. Large annual variations in total precipitation values commonly occur, due to large persistent storms or long term (months to years) draughts (TRIGOM, 1974). Snowfall is latitude related with an average of 2 inches per year at Cape Hatteras to between 60 and 100 inches along the Maine Coast.

(6) Storms and Storm Surge

The entire Atlantic coast experiences both tropical and extratropical cyclones (storms occurring around low pressure centers having counterclockwise winds). Tropical cyclones originate from 10°N to 30°N latitude where relatively warm (26-27°C.) surface waters serve as sources of formation energy. A tropical storm has several classifications based upon wind speed. A depression has surface winds of less than 33 knots. A tropical storm has winds from 33 to 63 knots. A hurricane has winds in excess of 63 knots (URI, 1974). A total of 290 hurricanes have been observed from 1901 to 1963. The majority of storms occurring along the South and Central Atlantic coast originate south of Cape Hatteras.

Several factors effect cyclogensis (formation of cyclones). Sharp thermal air gradients, formed when warm moist (warmed by the ocean) air masses are in close proximity with cooler continental (cooled by land) air masses, serve as energy sources for cyclogensis. This thermal gradient may be intensified by the position of the Gulf Stream and the upper air cold polar front. The peak time for tropical storms is from June to October. The maximum occurrence of these phenomena occur in August and September when an average of 8 hurricane days and 15 tropical storm days occur.

As described earlier, storms may result in large wind waves in conjunction with storm surges. Storm surges are elevations in sea levels formed by reduction in atmospheric pressure and the piling up of water on the coastline as a result of wind generated currents (Edinger, 1967). The effects of these storm surges may be enhanced by increased land run-offs as a result of heavy rains. The destructiveness of storm surges and heavy seas is at a maximum where coasts are low and densely populated.

Cyclogensis of extratropical storms is most common from October through April. These storms are generally weaker than tropical cyclones. The Central and South Atlantic regions lie within the primary track of these extratropical disturbances throughout the year (TRIGOM, 1974).

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c. Physical Oceanography

The shelf hydrography of the South Atlantic region is influenced by two major factors: the Gulf Stream and the weather. The Gulf Stream flows from the Straits of Florida northward along the shelf break and supplies the shelf waters with warm saline water. Water from the Gulf Stream enters the shelf waters by irregular meanders or lens formations (discrete parcels retaining the physical properties of their origin waters). The influence of local conditions, particularly air temperature, precipitation, wind speed and direction are particularly prominant upon shelf hydrography along the South Atlantic region.

Bumpus and Pierce (1955, from VIMS, 1974) have defined two different water masses on the shelf of the South Atlantic region: Carolinian and Virginian. The Carolinian water mass (shelf water found from Cape Hatteras south) is composed of Gulf Stream water, slope water, and river effluents from estuaries north of Cape Hatteras. Virginian water (shelf water generally found from Cape Cod to Cape Hatteras) is generally cooler and less saline, although the difference from Carolinian water may occasionally be small. The close proximity of the coast to the Gulf Stream precludes existence of a shelf water mass such as is found north of Cape Hatteras. Outer shelf waters south of Cape Hatteras are similar in temperature and salinity to the Gulf Stream. Coastal waters show large seasonal changes of temperature and salinity. Shelf water has been described by Kurada and Marland (1973) as being found nearshore and having salinities between 34.5 ppt. and 36.0 ppt. throughout the year. Inshore can be found the Coastal water mass which has lower temperatures and salinities than the Shelf water. There is little interchange of these southern waters with the water masses north of Cape Hatteras.

Waters occurring on the Central Atlantic shelf are formed from waters flowing southward along the coast and river effluents from the major coastal estuaries both within the region and to the north. Discrete parcels of water (lenses) are broken off the western edge of the Gulf Stream and move westward over the shelf where they ultimately become mixed with the shelf waters. This phenomenon explains the occasional presence of tropical biota north of Cape Hatteras (URI, 1974). The effects of the Gulf Stream on the biota are quite irregular north of Cape Hatteras as the core of the current is seaward of the shelf break (Figure 18). In the North Atlantic region, water enters the shelf from three major sources: 1) the Bay of Fundy, 2) the western basin of the Gulf of Maine, and 3) estuarine discharge.

Slope water which is found north of Cape Hatteras is formed by mixing from oceanic water and river effluents, and tends to have

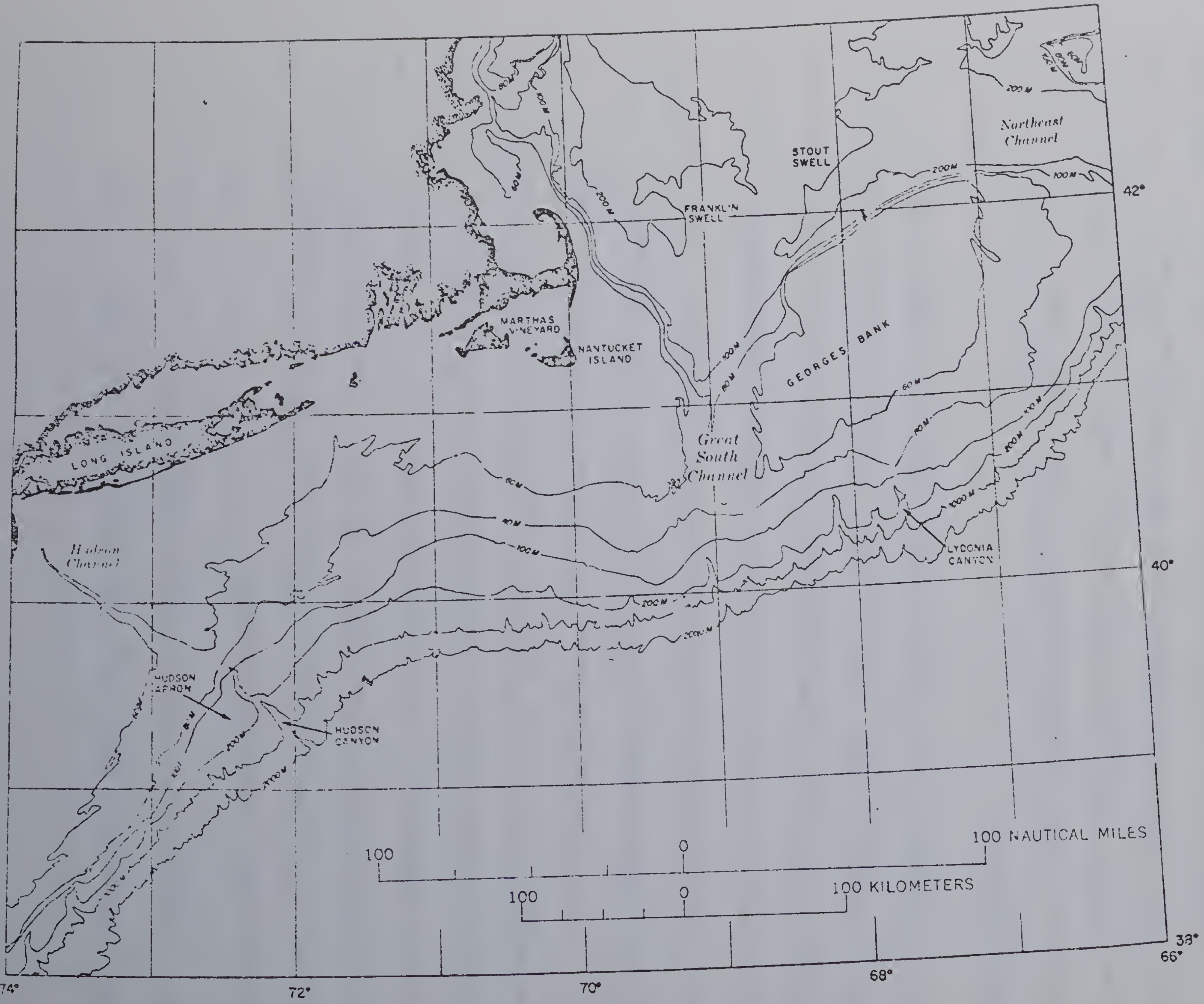


FIGURE 18.

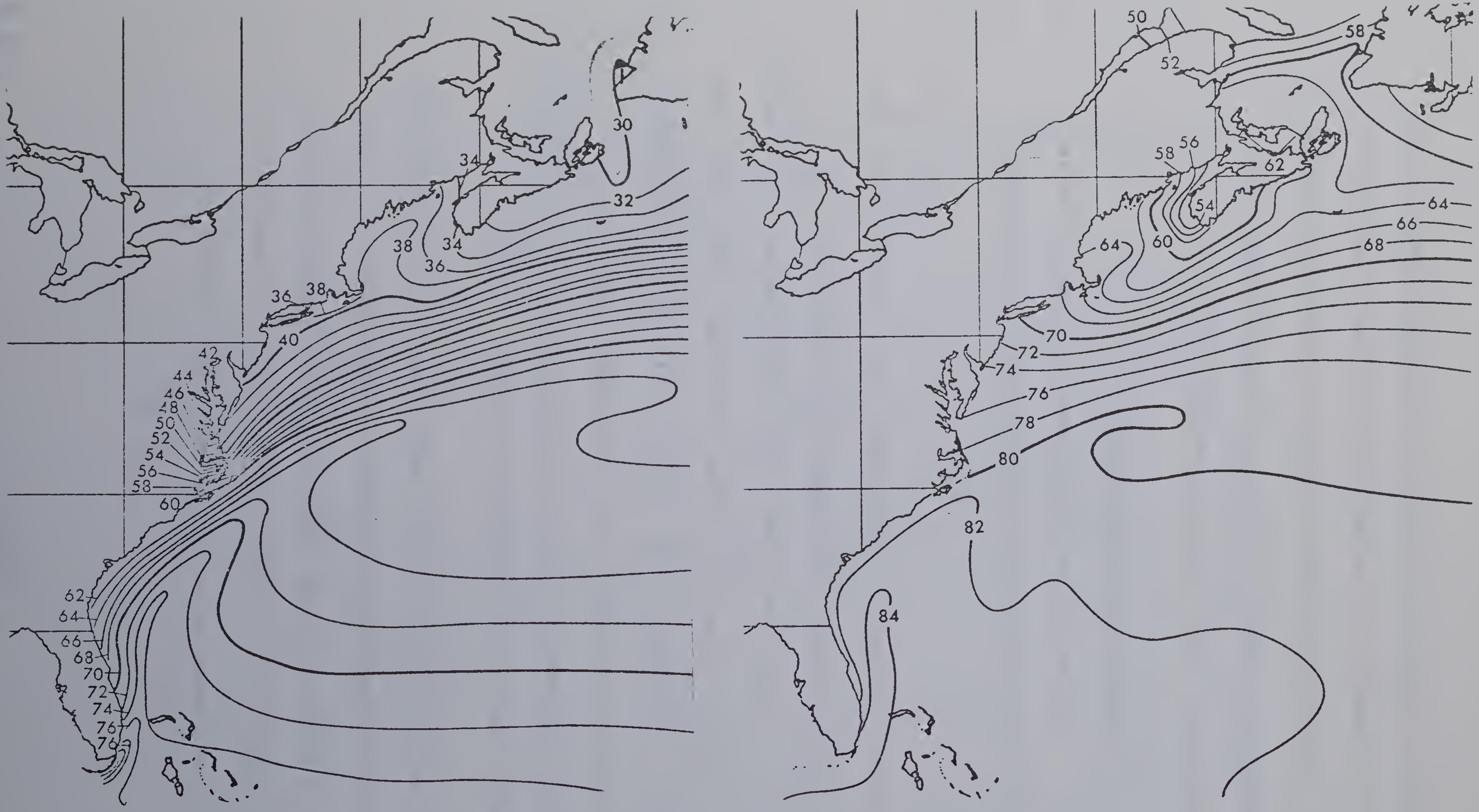
Geographic Location Map Of The Southern Portion Of The Gulf of Maine consistent physical properties throughout its range (Bumpus, 1973). Coastal water is formed by 1) the addition of slope water on the southern edge, 2) an influx of water through the Northeast Channel from the Scotian Shelf, and 3) an influx of estuarine water and occasional intrusions of Gulf Stream water (Fig. 18).

(1) Surface Sea Temperatures

Figures 19 and 20 represent average sea surface temperatures for February and August based on data collected from 1854 to 1958.

The surface isotherms (lines of equal temperature) parallel the coast in the South Atlantic region, with temperatures increasing with distance offshore. During the winter months this gradient of temperatures is more defined because the coastal waters are much cooler than the Gulf Stream. As warming occurs during spring and early summer, this gradient becomes less sharp and by mid-summer, surface shelf waters are nearly isothermal. Autumn cooling reverses this trend rapidly and winter conditions are quickly reached.

Waters on the Central Atlantic region shelf show seasonal variations from 3°C. in the New York Bight in February to more than 27°C. off Cape Hatteras in August. Annual ranges of surface temperatures in any area may exceed 15°C. in slope water and 20°C. in coastal water. Sea surface temperatures are at an annual minimum in



WINTER

SUMMER

FIGURES 19 and 20

MEAN SEA SURFACE TEMPERATURES (°F)

From U. S. Naval Oceanographic Atlas, H. O. No. 700

February with no consistent latitudinal variations. Isotherms run parallel to the coastline. Normal winter temperatures are 2-3°C. near the coast, 7-11°C. along the 200 meter isobath (line of equal depth contour) westward to New York, 3-4°C. coastwise and 9-10°C. off of Cape May, and 5° coastwise and 9-10°C. off of the Cheasapeake Bay. The water column approaches isothermal conditions from surface to bottom over the shelf during the winter. The maximum temperatures can be found at 150-250 meters along the slope with colder water above and below.

Irregular warming of the surface layers begins in late February. Initially this warming takes place throughout the water column with most rapid warming of the entire water column occurring near land. Beginning in late April, the surface layers are warmed much more rapidly than the underlying water, resulting in the formation of a thermocline (a steep vertical thermal gradient). After May the differences in surface temperatures north and south of Cape Hatteras are no longer present.

Surface warming occurs throughout the summer resulting in a more defined thermocline except at Nantucket Shoals where turbulence occurs from surface to bottom. Local upwelling due to winds blowing from west to east in conjunction with the bottom topography may cause local cold water pockets on the surface. The thermal gradient from surface to bottom may reach its maximum of 9-11°C. at Chesapeake Bay and 13-16°C. at Cape May in late August.

Fall cooling of surface water first results in the column approaching equal temperatures throughout. The speed of fall cooling is determined by air temperature and wind induced water mixing. By middle November, surface sea temperatures become horizontally isothermal across the shelf. Surface temperatures of 10-14°C. can be expected throughout the region at this time. The water column at this time is vertically isothermal to about 80 meters. By mid-January, waters are 5-6°C. surface to bottom along the coast, 8-9°C. midway out on the shelf, and 10-12°C. along the outer shelf edge. Minimum temperatures are reached in late February or March.

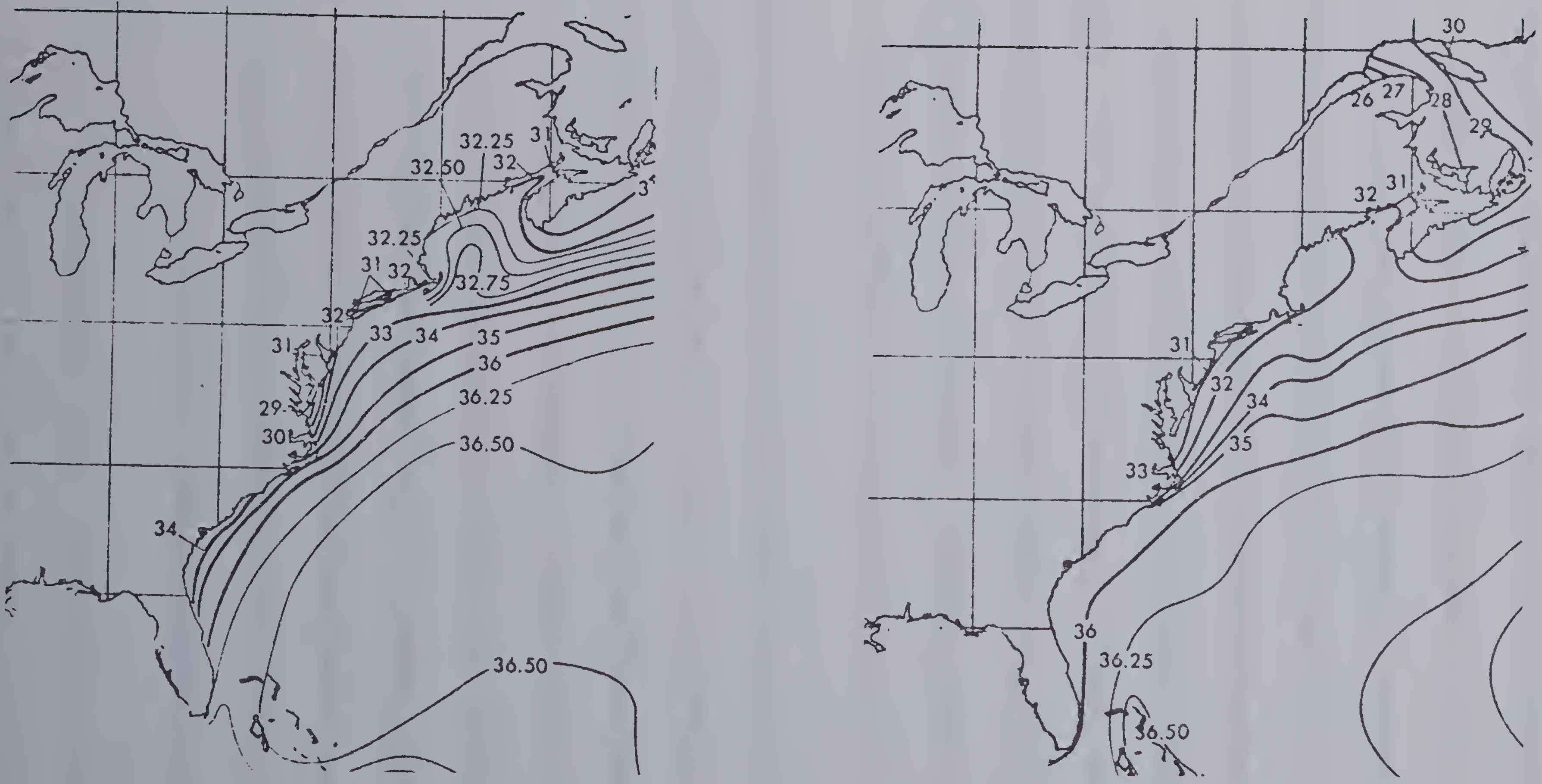
The Bay of Fundy and Georges Bank are areas of sufficient tidal mixing to inhibit the formation of a summer thermocline. A large range of sea surface temperatures exists between the coastal water and slope water throughout the year. Slope waters show temperature gradients during winter, and essentially isothermal conditions during fall and spring, due primarily to wind induced mixing. Coastal water is affected by seasonal air temperatures and river runoff. Summer sea surface temperatures decrease from southwest to northeast offshore the Gulf of Maine and increase on the bottom in the same direction.

(2) Salinity

Low amounts of estuarine effluents and the proximity of the Gulf Stream contribute to the high salinity of shelf waters south of Cape Hatteras. Surface salinities are quite variable but generally surface salinity contours parallel the coastline with salinities increasing offshore to 36 ppt at the western edge of the Gulf Stream. Figures 21 and 22 present average winter and summer salinities. River runoff affects surface salinities with resultant lowest shelf salinities when peak runoff occurs in winter and spring. Colder less saline Virginia water may intrude south of Cape Hatteras to Cape Fear as a result of prolonged northeast winter and spring winds. Highest salinities occur all along the coast during summer and fall.

Stefansson et al. (1971, in VIMS, 1974) describes meanders (deviations from the average course) of the Gulf Stream which renew shelf water. Average seasonal surface shelf salinities range from less than 32 ppt in April to greater than 34 ppt in September. Stefansson et al. (ibid.) have calculated that with strong persistent northeast winds driving Virginia water south of Cape Hatteras that the shelf experiences flushing (complete replacement of water) times on the order of 14 days. Without this intrusion of Virginia water, the flushing time would be approximately 200 days.

North of Cape Hatteras, different conditions prevail. Shelf waters show little longshore difference in salinities from the Bay of



WINTER

SUMMER

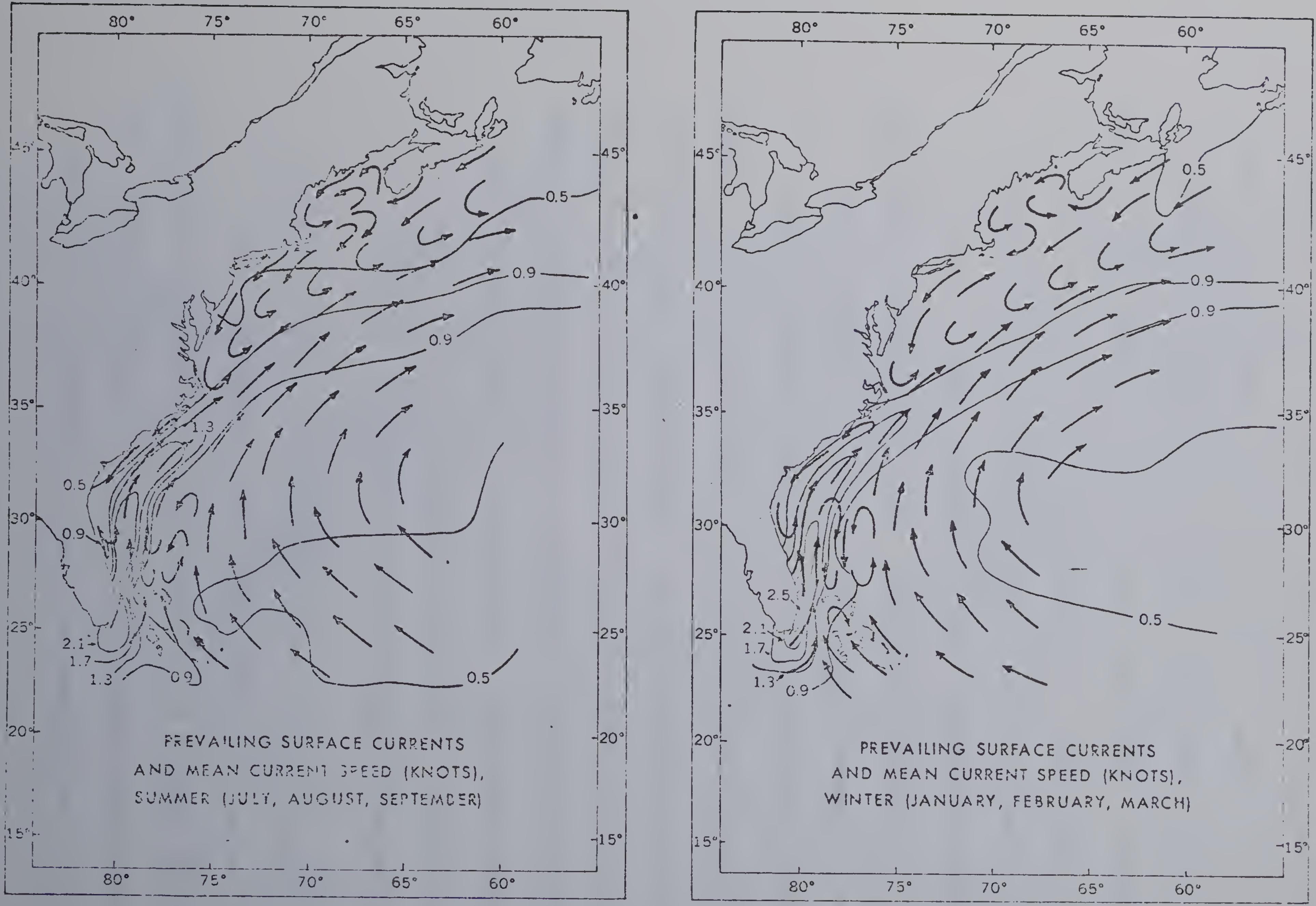
FIGURES 21 and 22

MEAN SEA SURFACE SALINITY

From Naval Oceanographic Atlas H. O. 700

Fundy to Cape Hatteras. The annual salinity variation is caused by fresh water runoff and intrusion of saline waters from the slope. Normal surface salinities range from 32 ppt near land to 32-33 ppt on mid-shelf to 34-35 ppt at the shelf edge. Surface salinities are highest in late winter and lowest in late spring. The winter values average 34.1 ppt at the slope, 33.5 ppt. along the mid-shelf and 32-33 ppt near shore. An average of 50% of all river outflow in the Middle Atlantic region occurs during March, April and May. During this season of peak runoff, a shoreward band of water of less than 32 ppt salinity is formed. The effluents from Long Island Sound appears to spread offshore and westward; discharge from New York Harbor flows offshore and southward and Delaware and Chesapeake Bay outflows are mixed with nearby coastal water. Waters of less than 32 ppt salinity may be found 100 miles seaward of the mouth of Long Island Sound and 50 miles from the mouth of Chesapeake Bay. Steep vertical salinity gradients develop on the shelf during these freshening conditions, which remain through July and August during normal years. Turbulence hinders formation of steep salinity gradients on Nantucket Shoals throughout the year.

Autumnal cooling of surface waters weakens the stability of the water column across the shelf, permitting greater vertical mixing. Mixing results in increased surface salinity and dissipation of low salinity water-cells near the mouths of major estuaries. The winter pattern of salinities is normally established by December.


80°
75°
70°
65°
60°
45°
40°
35°
30°
25°
20°
15°
0.5
0.9
1.3
1.7
2.1
2.5
PREVAILING SURFACE CURRENTS AND MEAN CURRENT SPEED (KNOTS), SUMMER (JULY, AUGUST, SEPTEMBER)
PREVAILING SURFACE CURRENTS AND MEAN CURRENT SPEED (KNOTS), WINTER (JANUARY, FEBRUARY, MARCH)

FIGURES 23 and 24

Mean Surface Currents Summer and Winter (Atlantic Ocean)

Modified from U. S. Naval Oceanographic Atlas H. O. 700

Uniform winter surface salinities are normally found in the North Atlantic region shelf also. However, this uniformity is not found in slope water during the winter. Lower salinity water (30-32 ppt) from Nova Scotia enters the Gulf of Maine during the winter. River runoff results in salinities of less than 32.5 ppt around the periphery of the Gulf of Maine and Georges Banks. During spring freshening, lower salinities generally prevail throughout the region except where strong gradients exist in the slope water. Stratification (layering of waters of differing physical properties) occurs in the upper layers in spring. Differences in subsurface salinities in various basins in the Gulf of Maine may be related to their individual sill (the low part of a ridge separating deep basins) depth. The Laborador Current flowing southward makes only minor seasonal contributions to the Gulf of Maine waters. Waters in the Gulf of Maine are primarily composed of slope water (Bigelow,1927 in TRIGOM, 1974).

(3) Surface Circulation

Shelf circulation, south of Cape Hatteras, is controlled primarily by the Gulf Stream, winds, and freshwater inflows from the coastal estuaries (Figures 23 and 24). Tidal currents are weak and rotary (showing flow throughout the tidal cycle) having slight influence on shelf circulation. Coriolis Force (the apparent force exerted on moving objects due to the earth's rotation) is minimal on the shelf due to shallow water depths.

A northeast drift occurs on the South Atlantic region shelf as a result of prevailing winds, frictional drag from the Gulf Stream, river runoff and the cross-shelf density gradient due to spatial differences. Gulf Stream surface velocities may reach 2 knots (150 cm/sec) at the edge of the shelf. Surface currents run northeasterly along the Carolinas and intermittent off Georgia and Florida, where northerly currents occur in winter and autumn (Bumpus and Chase, 1965 in VIMS, 1974). Nearshore currents tend to run in opposite directions to slope currents and flow southerly during most of the year (Bumpus and Laugier, 1965).

Bumpus (1973 in VIMS, 1974) interpreted drift bottle data for 1960-1970 to indicate a northerly component to the drift from off Georgia to Cape Hatteras in January, with a southerly flow along the Florida coast to where the shelf narrows south of Cape Canaveral. This southerly drift remains until April and may contain parcels of Virginia water. Currents in the Straits of Florida are northerly year-round as far north as Cape Canaveral and swings offshore to a northerly direction on the outer shelf until the latitude of Cape Lookout. Current speeds are approximately 0.2 knots.

In general, a northerly drift over the entire southern shelf exists in the cooler months except in the vicinity of Cape Hatteras where local wind effects predominate. A reversal in this pattern has been observed for the warmer months, with a southerly flow predominant.

Generally, surface currents on the Middle Atlantic Bight shelf flow southward with the coastline to the right at speeds of approximately 0.4 knots (20 cm/sec.). A shoreward component of this shift may exist during the warm months and an offshore component may occur during the cooler seasons. The surface current is partly resultant from density gradients across the shelf and partly to local persistent wind conditions. A mechanism for salt flux (flow of water or other material) into the estuaries has been described as a persistent bottom drift of the order of tenths of a mile per day, flowing from the mid-shelf shoreward.

Surface circulation patterns are more complex along the North Atlantic region shelf. In this region, major river runoff, complex bathymetry, seasonally high winds, intrusion of slope water, and tidal actions combine to produce these complex circulation patterns.

Generally a westward current is formed on the slope opposing a northeastward current of slope water adjacent to the Gulf Stream. This westward drift joins the Georges Bank eddy (a circular current formed when currents pass over obstructions) on the southern edge of the Bank. This flow splits, one portion moving westward across the shelf to the area off Rhode Island, the other portion moving northward to become entrained in an eastward flow moving across the northern edge of Georges Banks. A southerly flowing limb closes the eddy on Georges Bank. This eddy occurs during spring. The summer drift at the eastern edge of Georges Bank is southerly and offshore, and by autumn the drift along the western edge is southwesterly. Winter flow patterns in the region show a southerly drift throughout. A counterclockwise Gulf of Maine eddy occurs just north of Georges Banks. Input of water from the Scotian Shelf and Browns Bank flowing westward contributes to the northern limb of this eddy. This intrusion either continues westward down along the coastline or moves northward into the Bay of Fundy. This eddy is also seasonal, slowing by summer with the southern limb dissipating into a flow across Georges Banks during autumn and winter. Surface currents in the Gulf of Maine are slow in winter and spring (1 to 4 nautical miles per day), increasing during the summer (7 to 8 nautical miles per day) and reducing slightly to (5 to 6 nautical miles per day) during fall and winter. Wind, water density differences and river runoff are causal forces in current formation. Coriolis force and complex bathymetry are the steering factors to these currents. Coriolis force is partly responsible for turning river runoff to the right resulting in a southerly current along the coastline. Generally currents follow bottom contours in the Gulf of Maine.

This summary of surface circulation is based on sparse data. Moderate to large storm systems can greatly modify normal circulation patterns both by wind induced currents and by increased coastal runoff. The average conditions described above may bear little resemblence to field conditions at any given time.

(4) Tides

Tides are fluctuations in sea level due to the gravitational attraction of the sun and primarily the moon and by the centrifugal force of the earth moon system. Coriolis force, friction over bottom, and local bathymetric features all influence the amplitude and periodicity of the tidal cycle. Tidal currents and heights are of little concern offshore. These offshore tidal currents are rotary and usually quite weak.

Nearshore and shoreline bathymetry modifies tidal action by restricting normal passage of tidal currents causing surface level build-up and local currents. The phases of the moon also influence the tides. Higher than average tides (spring tides) occur during the full and new moons and neap tides (smaller than average) occur during the first and third lunar quarters. Along the entire East Coast, tidal motion is semidiurnal, having two complete cycles every lunar day (24.8 hours). The tide at Cape Canaveral precedes that at Cape Hatteras by approximately one hour. Spring tidal heights vary from 4 feet at Cape Canaveral, to 8 feet at Savannah to 3 feet at Cape

Hatteras. Tidal height offshore the South Atlantic region seldom exceeds 2 feet.

Tidal currents offshore of the Central Atlantic Region are weak (less than 0.1 knot), semi-diurnal, and rotary as in the South Atlantic region. Only nearshore and between embayments or basins does tidal current and height become readily apparent. As in other regions, tidal currents from other sources. These currents would include river outflow and storm surge. Three separate tidal motions occur nearshore in all the Atlantic regions. These are: the dominant semidiurnal tides, with periods of one-half days, diurnal tides with periods of one lunar day, and longer period tidal oscillations with periods of one half of a month or more. At Boston Light, the spring tidal range is 9 feet and at Eastport, Maine, it is 20 feet. Thus tidal motion influences circulation significantly only nearshore and practically not at all offshore.

(5) Sea and Swell

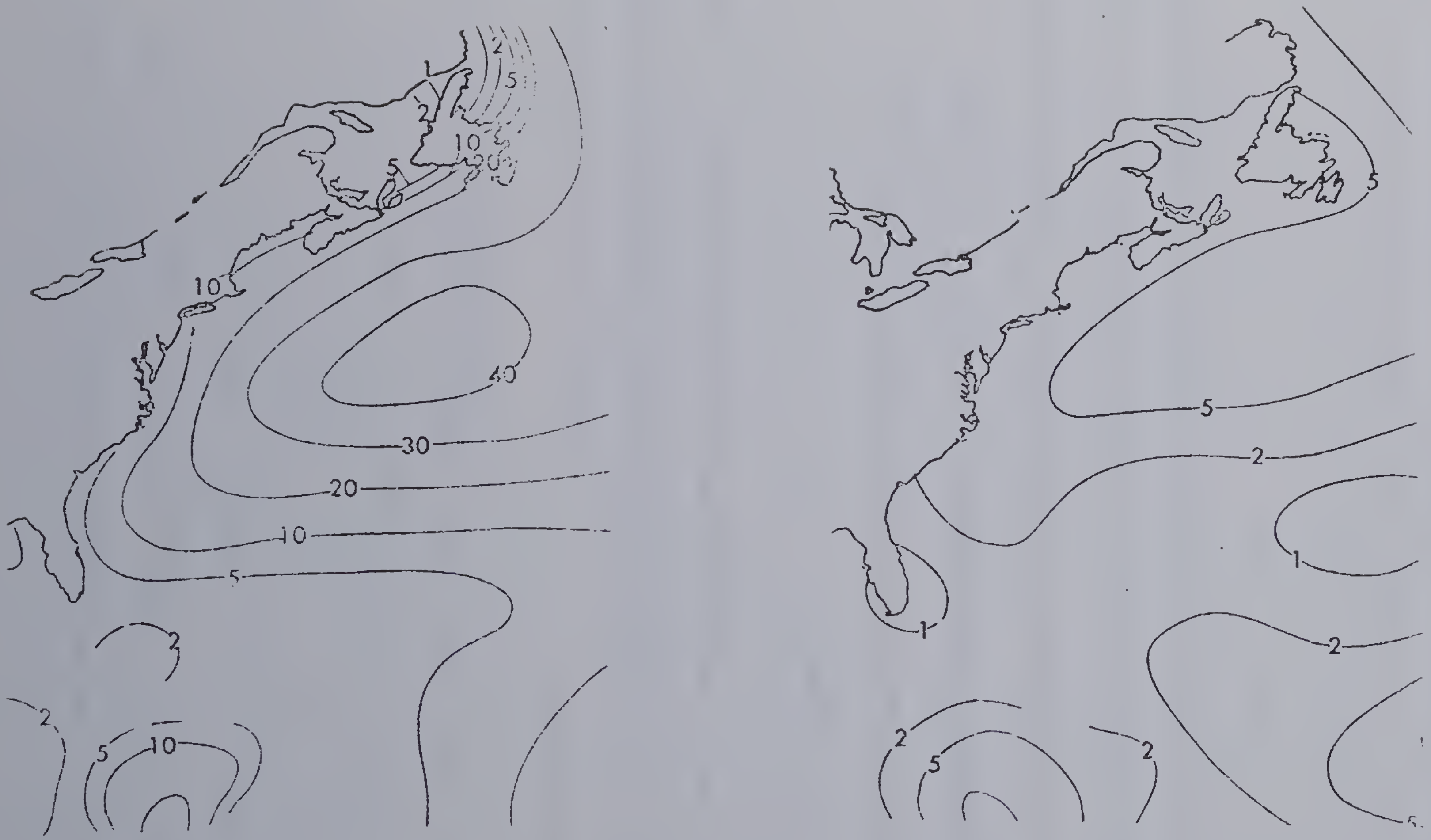
Surface waves are produced mainly by surface winds and modified by other factors. Wave sizes are functions of wind speed, the period of time the wind has been blowing steadily from a given direction, fetch (the distance of unobstructed water subject to the wind force), relative velocity of surface currents to wind velocity, and depth of water in the area of wave generation.

Wave parameters include: 1) wave height (H), the distance between trough and crest, 2) period (T), the time it takes one wave length to pass a given point, 3) wave length (L), the horizontal distance between two successive crests or troughs. An increase in wind velocity, wind duration, or fetch will yield an increase in the wave height.

Waves occur only in the area under the influence of the generating wind. Swell is the term used for decaying waves that are no longer under the generating influence of surface winds. While either sea or swell are encountered at any given location, it is their simultaneous occurrence in an area that causes confused sea conditions most of the time.

Wave conditions are more severe during the stormy seasons of fall and winter. Annual and seasonal average wave conditions are contained in Figures 25 and 26.

Maximum theoretical wave heights have been calculated (U.S. Dept. of Commerce, 1973), assuming unlimited fetch and duration; these predicted wave heights are: a wave exceeding 51 feet every 2 years, 71 feet every 5 years, 84 feet every 10 years, 100 feet every 25 years and 112 feet every 50 years. Although these wave height values are theoretical, waves exceeding 35 feet are not uncommon on the shelf.



WINTER

SUMMER

FIGURES 25 and 26

PERCENT FREQUENCY OF SEAS > 8 FEET

From U. S. Naval Oceanographic Atlas H. O. No. 700

Waves tend to "feel bottom" when the water depth is less than one-half of the wave length. Upon shoaling, waves refract (inshore portions slow causing wave crests to bend toward the parallel to the coastline) toward the shallower water, steepen, slow down, and finally break when critical steepness is reached (surf or breakers).

Average seasonal wave conditions for the Central Atlantic region are contained in Figures 25 and 26 . During the winter, waves higher than 20 feet have been reported 2% of the time. Thorn (1971, in URI, 1974) computed the time of recurrence of extreme waves as being one 45 foot wave every two years and one 105 foot wave every 50 years.

Average seasonal wave conditions for the North Atlantic region are contained in Figures 25 and 26 . Wave patterns in the Gulf of Maine are generally confused. Neu (1972 in TRIGOM, 1974) predicts a one year maximum wave within the Gulf is 30 feet. One year maximum waves on Brown's and Georges Banks are 35 to 40 feet. The 100 year predicted wave for Georges Banks is 67 feet. A storm generated wave in the Atlantic over 112 feet in height was reported by U.S.S. Ramapo, in 1933 (Bascom, 1964).

(6) Ice Conditions

Sea ice rafting and iceberg movements should offer no operational hazards in any of the Atlantic regions. Rigs and ships operating on the northern Georges Banks might expect to find a moderate rate of ice formation (1.5 to 2.5 inches/hour) on their exposed structures for several days in February (Council on Environmental Quality, 1974).

Ice formation occurs in estuaries and rivers from the Chesapeake Bay northward. Ice of sufficient thickness to hamper navigation normally occurs in the majority of Maine harbors during normal winter conditions.

d. The Biological Environment

The Atlantic coastline falls within four broad zoogeographic zones: 1) the Boreal which runs from Newfoundland to Cape Cod; 2) the Virginian which runs from Cape Cod to Cape Hatteras; 3) the Carolinian which extends from Cape Hatteras to Cape Canaveral; and 4) the Caribbean from Cape Canaveral south. These zones are based upon the occurrences of species endemic (found only within the boundaries) to particular areas and correspond closely to zones which can be described by the physical characteristics of the sea water therein. The Gulf Stream currents have a profound influence on the seaward boundaries of these zones. The warm waters of the Gulf Stream are responsible for species common to the Virginian zone occurring on Georges Banks (Emery and Uchupi, 1972).

Biological organisms are normally classified according to several criteria, including: physiological, zoogeographical, and anatomical.

A classification based upon habitat and ability to move about will be used in this discussion. Plankton is a term used to specify all organisms which are not capable of sufficient motility to overcome prevailing water currents. Phytoplankton is a group that contains primary producers (plants). Zooplankton contain small animals and larval stages of other animals which are not planktonic throughout their life cycles. Meroplankton is a term used to classify those species which have planktonic stages during their life but are not planktonic in their adult forms. Holoplanktonic refers to those species which are planktonic throughout their life cycle. Benthos refers to species normally found associated with the bottom. Nekton describes animals which possess sufficient swimming ability to overcome opposing currents.

The water column may be broken down into the photic zone (those layers which receive sufficient sunlight for photosynthesis) and the aphotic zone (below sufficient light penetration for photosynthesis).

Phytoplankton

The occurrence and population levels of phytoplankton are governed by several factors including: 1) availability of nutrients; 2) light levels; 3) population origins; 4) life cycles; 5) temperature and salinity; 6) adaptability; 7) grazing pressures of zooplankton and other consumers; 8) physiological requirements; 9) vertical water mixing; and 10) water stability.

Phytoplankton dynamics are incompletely understood on the Atlantic shelf. Insufficient data currently exist to give other than cursory comparisons of plankton populations.

The dominant (in terms of biomass) species of phytoplankton on the South Atlantic region shelf were the diatoms Skeletonema costatum, *Leptocylindrus danicus*, and *Nitzsehia seriata* (Hulbert, 1967, in VIMS, 1974). The dominant species in the Gulf Stream were the coccoliths *Coccalithus huxlei* and *Umhilicosphaera tenuis*. Hulbert (ibid) found little species overlap of diatoms and coccoliths from the shelf to the Gulf Stream. Generally population numbers drop off seaward from the coast. Nitrate (NO_3) nitrogen appears to be the limiting nutrient to the phytoplankton community as available nitrate is virtually completely incorporated within the living cells except near estuaries (Ryther and Dunston, 1971). The flora of the shelf is complex and relative abundances of species may change with time and area. Marshal (1971, in VIMS, 1974) describes over 100 species of diatoms from the shelf, Gulf Stream, and seaward. Marshal found that *Skeletonema* was dominant on the shelf and other important diatoms included *Chaetoceros decipiens*, *Navicula* sp., *Rhizosolenia alata*, *Thalassionema nitzschioides* and *Rhizosolenia stolterfathii*.

Dinoflagellates are dominant on the shelf during the summer. Dominant species include *Amphidinium* sp., *Ceratium furca*, *C. fusus*, *C. tripas* and *Gynmodinium* sp.

Annual productivity was found to be high (547 grams of Carbon fixed per square meter [$gC/m^2/yr$]) in August with lower levels for the rest of the year. A definite correlation between river runoff and productivity exists. Production on an areal basis was lower nearshore, due to turbidity, than further offshore on the shelf (Thomas, 1966, in VIMS, 1974). The role of nutrients in annual cycles has not been explored.

A thermocline (sharp vertical temperature gradient) exists in the waters of the Central Atlantic region. This thermocline, which occurs from late spring to winter, limits circulation of nutrients from cooler waters up into the photic zone where they could become available to plankton. Throughout the existence of the thermocline, a continuous rain of dead animals and plants sink from the photic zone. These nutrients are lost from the surface layer until upwelling or fall and winter wind induced mixing occurs. Nutrients are thus in low concentrations in the growing zone. Populations on the Central Atlantic shelf are primarily diatoms. The rain of material serves as food for the animals below the photic zone, though.

The dominant species are *Rhizosolenia alata* in the summer and *Thalassionema nitzschoides*, *Skeletonema costatum*, *Asterionella japonica* and *Chaeteroceros socialis* in the winter. High productivity levels have been reported in December and March. During these months an 8-fold increase in populations (up to $3x10^8$ cells/liter of sea water) occur over summer levels (URI, 1974). Annual production for the inshore waters averages 160 g/C/m^2, 135 g/C/m^2 on the mid-shelf, and 100 g/C/m^2 offshore (VIMS, 1974).

Plankton are capable of surviving in large numbers only during the warmer seasons in the shelf waters of the North Atlantic region. Areas of vertical turbulence such as the Bay of Fundy and waters off the coastline eastward of Mount Desert Island remain too cold year round for plankton to reproduce (TRIGOM, 1974).

Plankton undergo seasonal cycles of abundance in response to the nutrient cycling. Fall cooling of surface waters results in destruction of the thermocline and vertical mixing returning nutrients back into the surface waters. Winter populations are low due to cold temperatures in the photic zone. Only when surface waters are warmed in fall or when the spring thermocline is initiated can plankton reproduce to significant levels. *Thalassioria* sp. is the first dominant diatom followed by *Chaetharus* sp.

The dominant organisms in the Gulf of Maine in the winter are the diatom *Cascinodiscus*, the dinoflagellates *Ceratium longipes*, *C. tripos*, *C. bucephalum* and the diatoms *Chaetoceros decipiens*, *C. atlanticum*, and *C. criophilum*. *Chaetoceros densum* becomes the dominant species during the spring plankton bloom. *Ceratium* is the dominant genus during the summer.

Insufficient data exists to predict the order of succession of phytoplanters in a given area (TRIGOM, 1974). The average annual production in the Gulf of Maine and North Atlantic shelf waters is 250 g/C/m^2 per year.

Population levels of certain species of phytoplankton may reach phenomenal densities of 4x10^7 cells per liter. Such an occurrence of certain species is called the "red tide". These high density explosions normally involve one or more of the following organisms:

the dinoflagellates *Ganyaulax cochlea*, *Amphidinium busilforme*, *Gyminodium splendens*, and *G. brevis*. These blooms are widespread and common along the Central and South Atlantic regions, especially in the estuaries. Products excreted by these organisms reach sufficiently high concentrations to occasionally cause skin irritations and respiratory infections of people working near the water, massive fish kills, paralytic shellfish poisoning, and potential human mortality if shellfish exposed to sufficient levels of the excreted toxins are consumed. Species of *Gonyaulax* have caused paralytic shellfish poisoning in the Gulf of Maine. These blooms most often occur following high levels of freshwater runoff, warm water temperatures, and sufficient sunlight (VIMS, 1974). Current beliefs are that these red tides are natural phenomena but that population levels may be increased due to nutrient enrichment in the form of pollution.

(2) *Zooplankton*

The population dynamics and levels of zooplankton are also incompletely understood for the Atlantic region. Major problems in data reporting include, lack of consistency in collecting net size, variations in depths of plankton tows, diversity of units used in reporting population levels, variations in seasonal occurrence and abundances of plankton, variations of physical and chemical properties of the seawater, relative variations in freshwater river runoff, and seasonal presence of meroplankton.

Zooplankton communities contain holoplankton and seasonal occurrence of large numbers of meroplankton. Zooplanktonic organisms are herbivores (feeds on plants exclusively), carnivores (feeds on animals only), or non-selective feeders (both). They show tendencies to undergo vertical diurnal migration which enables them some level of control over horizontal currents, however they do not possess the mobility to swim against prevailing currents.

The holoplanktonic community is primarily composed of copepods, chaetognaths (arrow worms), pterapods, coelenterates, molluscs, protozoans and others. The term meroplankton refers to eggs, larval, and post-larval stages of decapod crustacea, molluscs, polychaetes, coelenterates, and fishes. Tychoplankton are benthic animals which have been accidentally swept up into the water column or which occur occasionally during migrations, etc. The composition of tychoplankton is extremely variable and occasional. Zooplankton can be categorized by size, physiological tolerances, or geographical areas of occurrence. The factors that govern the composition and population levels within the planktonic community are incompletely understood. Seasonal and spatial changes in populations normally occur but cannot be explained. For the sake of discussion, plankton will be split into two categories: neritic (found between low water and the edge of the shelf), and oceanic (found seaward of the shelf). Oceanic plankton is generally composed almost totally of holoplankton, whereas the neritic community may be composed of predominantly meroplankters on a seasonal basis. The boundaries of these forms of plankton are not sharp, and overlaps normally occur. The factors determining these boundaries are only partially understood. Vitamins, coastal currents, planktonic excretions, temperature, salinity, nutrient levels, light levels, and others are recognized as being contributing factors to population distribution.

The zooplankton communities of the South Atlantic coastline have been incompletely investigated. Bowman (1971, in VIMS, 1974) has described 100 species of copepods in this region. Eighty-one species were primarily oceanic and three relatively consistent species relationships were described for neritic organisms. Acartia tonsa is the dominant species offshore and near the Saint Johns and Indian Rivers in Florida. The predominant coastwide species was Labidocera aestiva. No significant north-south changes can be found in this region, and species from this region may be dominant north of Cape Hatteras in the warmer seasons.

The dominant copepods on the mid to outer shelf are Paracalanus parerus, Centrophages furcatus, Eucalanus pileatus, and Temora turbinata. The dominant oceanic (seaward of the slope) organisms are Lucicutia flavicarnis, Temora stylifera, and others.

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Chaetognaths (arrow worms) are most common nearshore with Sagitta hispeida restricted to coastal waters and S. hexaptera, S. lyra, K. pacifica and Ptarosogitta dioco primarily found in the Gulf Stream waters (Pierce and Wass, 1962). No clear seasonal population changes are apparent (VIMS, 1974). Two species of decapods and 19 species of pteropods have been described along the South Atlantic coast (Williams, 1969; Chen and Hillman, 1970 in VIMS, 1974). The presence of life cycle stages of the crab Callinectes has been reported in both shelf and oceanic areas (VIMS, 1974). Generally, the total number of plankton per unit area decreases in the offshore direction but diversity increases.

Seasonal shifts in phytoplankton communities occur in the Middle Atlantic region. Two major shifts occur annually causing a boreal community in the winter-spring, and a temperate-tropical community in the summer and fall. The occurrence of these communities appears predominantly controlled by temperatures which inhibit the reproduction of the temperate-tropical group during the cooler seasons. Salinity also affect species composition of the community but specific effects are unclear (URI, 1974). Salinity is known to be a factor in the shifting of copepod dominance from Acartia clausi in the winter-spring season to A. tonsa during the summer-fall period. Zooplankton population levels are controlled by predation and protozoan infestations as well as by physical parameters. Insufficient information exists to adequately describe the zooplankton community along the Central Atlantic coast. Reports dealing with this area are not generally comparable due to seasonal variations, inadequate and non-comparable sampling programs, diversity in units used in findings, inadequate cruise durations, etc. (URI, 1974).

Neritic zooplankton occur from shore to the 100 meter isobath (a line drawn along a contour of equal values) along the North Atlantic region coastline. This includes most of the Gulf of Maine, and Georges and Browns Banks. Meroplankton forms are predominantly restricted to these waters. Predominant neritic species include the copepods *Temora longicornus*, *Labidocera aestiva*, *Centrophages typicus*, *Pseudocalanus minutus* and *Oisthana similis*, cirriped larva, and cladocerans *Podon* spp. and *Evadne normandii* (TRIGOM, 1974).

A series of reports by Sherman (1966, 1968, and 1970) describes consistencies and variations in the zooplanktonic community from 1964 to 1968. The average annual dominant copepods were *Calanus finmarchius*, *Centrophages typicus*, *C. hamatus*, *Pseudocalanus minutus*, *Temora longicornis*, *Acartia clausii*, *Eutemora herdmani* and *Oithana* spp. These varied from year to year with respect to relative abundance and range. The deep basins in the Gulf of Maine are occupied by oceanic species. Winter cooling of surface waters results in reduced rates of reproduction and lessening in populations.

Zooplankton constitute the primary biological factor regulating the size of phytoplankton populations, and are important in energy flow through the food web.

(3) Benthic Biota

Benthos, organisms who normally live in, or near the bottom, may be classified as inbenthos (those animals found below the water-sediment interface) and epibenthos (those animals found above the surface of the bottom).

The distributions of benthic organisms are governed by complex interactions of physical and biological factors. The specific physical characteristic of the surficial sediments is a major factor in zonation. Hard substrates such as rock or wood actually support a more varied assemblage than do unconsolidated substrates e.g., sand and mud. The physiological capabilities of each species to tolerate temperatures and salinities normally found in given regions also is a governing factor. The presence of stresses such as bottom currents, wave induced turbulence, and pollution also are major factors in benthos zonation.

The shelf substrate of the South Atlantic Region is primarily composed of medium grained sand and shell. Silty sand occurs near the mouths of estuaries. The zoogeographic regions described in the section on plankton are much in evidence for benthos. The sharp temperature gradients at Cape Hatteras and Cape Canaveral mark the northern and southern boundaries of many organisms found in this region. Caribbean fauna exist throughout this region offshore the mid-shelf. The nearshore shelf (0-40 meters depth) is characterized by a detritus feeder community type, several filter feeders, and a few carnivores. The dominant species are *Mellita quinquiesperforata* (sand dollar), *Polygordius* (an arachiannelid), *Macroclymene zonalis* (a polychaete) *Spisula raveneli* (surf clam), and *Olivella mutica* (a gastropod) (VIMS, 1974). The outer continental shelf (40 to 120 meters) is below normal wave action effects and the biota here is more complex. A total of 90 species were reported as prevalent in this zone by Day, et al. (1971 in VIMS, 1974). Polychaetes are the most common taxanomic group, at times accounting for more than 50% of the total benthic biomass. The dominant organisms are *Polygordius* sp. an annelid, polychaetes *Palaenatus heteroseta*, *Pseudeurythae amlugira*, *Magelona papillicarnis*, amphipods *Plotyischnopus*, *Maera*, gastropods *Olivella adelae*, *O. mutica*, echinoderms *Mellita quinguiesperforata*, polychaetes *Oniuphis nebulosa*, *Chaetozone setosa*, amphipods *Paraphaxus* sp., and *Siphanaecetes maculicarnis*, and others (Day, et al., 1971, in VIMS, 1974). Quantitative studies of energy flow through the benthic community has been completed on one station only; thus insufficient data exist for generalizations in this region. The diversity commonly found in benthic studies is indicated by Leiper's work (1973 in VIMS, 1974) at three stations off Georgia which yielded a total of 322 species in 21 phyla. Currently it is not possible to discuss faunal homogeneity of offshore bottom benthos in this region (VIMS, 1974).

Three level bottom biotic assemblages have been described for the Central Atlantic region. These are the sand, silty sand, and silt-clay assemblages.

The sand fauna are found primarily from a depth of several to 30-50 meters. The polychaetes *Spisula solidissma*, *Astarte castanea*, *Ensis directres*, gastropods *Polinices duplicatus*, *Lunatia heros*, several amphipods, decapods *Crangon septemspinosus*, *Cancer irroratus*, *Echinarachinus parma*, and anemone (URI, 1974). This sandy community type apparently extends from Cape Hatteras to Cape Cod and is also found on Georges Banks. Reported data are insufficient to describe energy flow through the community, but its importance as a feeding area for the Georges Banks fish and its resultant economic importance has been recognized (URI, 1974).

The silt-sand community may be found in large areas on the shelf. The following organisms are common to dominant on this bottom community type; polychaetes *Pherusa affinis*, *Clymella tarquata*, bivalves *Arctica islandica*, *Carditan borealis*, amphipods *Ampelisca* *vadarum*, *A. verrilli*, several deposit feeding crustaceans and one species of anemone.

Silt-clay fauna are primarily restricted to estuaries and shelf areas at their mouths. This assemblage of organisms include many deposit feeding polychaetes and bivalves and the echinoderms *Briaster fragilis*, *Ophiura sarsi* and *Ctenadiscus crispatus*.

Fauna found in submarine canyons in this region differ from organisms found on the relatively flat shelf bottom. Insufficient reports exist to describe communities normally associated with this type of habitat (URI, 1974).

The North Atlantic region contains two zones based upon temperature and salinity, the Boreal which extends from Newfoundland to Cape Cod and the Virginian which extends from Cape Cod to Cape Hatteras. Some species occur in both regions, however Cape Cod forms the boundary for most benthic organisms in this region. The commercial ocean quahog *Arctica* and the surf clam *Spisula* occur on opposite sides of this boundary in the same niche (functional role in the community) (Odum, 1971). Several areas occur in this region which can best be classified as relict communities. These assemblages were formed when oceanic conditions were warmer, and have persisted in local areas even though the physical water properties are no longer favorable. This is the acceptable explanation for the occurrence of numerous small oyster and quahog clam beds along the New Hampshire and Maine coast (TRIGOM, 1974).

Four community types have been described by Wigley (1968, in VIMS, 1974). These assemblages have been categorized by the substrate they most frequently colonize. They are the sand, silty-sand, gravel, and mud bottom types. The number of organisms in each of these community types is high. Characteristic organisms of the sand assemblage including the sand dollar *Echinarachnius parma*, the moon snail *Lunatia heros*, pink snail *Nassarius trivittatus*, the surf clam *Spisula solidissima*, the sand shrimp *Crangnon septemspinosus* and others. The silty-sand community was composed primarily of the brittle star *Amphioplus abdita*, the sea cucumber *Thyone scabra*, the ocean quahog *Arctica icelandica*, a snail *Colus pygmaeus* and others. The most common species in the mud bottom community were the urchin *Briaster fragilis*, the brittle star *Ophuira sarsi*, another brittle star *O. robusta*, shrimp *Pandalus* spp. and more. Organisms normally associated with a gravel bottom were the sponge *Cliona*, another sponge *Polymastia*, the hydroid *Turbularia*, the bivalve *Modiolis*, *nudlibranchs*, the starfishes *Solastar* and *Crossoster*, tunicates and others (Wigley, 1968, in TRIGOM, 1974). Insufficient data exist on the life cycle, numbers, breeding behavior, survival rate, and habitats of most of the benthic organisms to make detailed analyses. Researches do not agree on the degree of association of these organisms and thus the terms assemblage or community type have been used rather than community which denotes a degree of mutual interpendence of one organism on another.

(4) Active Swimmers - Nekton

Nekton is the term used to describe organisms which are capable of swimming against currents. Most of the nekton is comprised of fishes, marine mammals, molluscs, and crustacea.

The coastline of the Atlantic Coast is indented with numerous embayments. These estuaries are utilized by many of the commercially important fish species throughout the area. Shad, striped bass, and river herring are among the species which spawn in tidal marshes. The young of these species use these estuary areas as feeding grounds. The larval and juvenile forms of the flounders, menhaden, sea bass, shrimp, eels, and mullet are transported into the estuaries from offshore spawning grounds. Fish which seasonally feed in the estuary include the shrimp, striped bass, flounders, menhaden, and others (TRIGOM, 1974). The offshore - onshore boundary does not hold for the Atlantic fishes. Thus this description for nekton will include the onshore areas as well as offshore.

The South Atlantic Region Shelf falls within the Caribbean zoogeographic zone. The shelf is smooth, flat and sandy with the exception of several offshore areas and around the mouths of the

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estuaries where the bottom is normally muddy. The inshore area (less than 20 meter water depth) has been historically fished for shrimp, crabs, spot, croaker, kingfish, and sea trout. This area normally undergoes seasonal changes in temperature and salinity from surface to bottom. The offshore area (20 - 200 meters) is not significantly affected by seasonal air temperatures. This area is affected by the Gulf Stream and thus is warmer than the inshore areas during winter and spring. This area is normally fished for the calico scallop, snappers, groupers and porgies. Rock outcroppings and reefs, to be discussed later, have been found off the coast of North Carolina. These hard substrates are isolated and provide productive snapper and grouper fisheries (VIMS, 1974).

The commercial fisheries data for the region (1972) indicate that 284,168,000 pounds of fish and shellfish were landed in that year representing a total value of $44,309,000. The total 1973 landings for the South Atlantic Region was 241,057,000 pounds at a total value of $56,658,000. A more detailed description of the Atlantic fisheries will be given later in this paper in the section describing resources. Catch data for each state in this region varied but agreement on the five most important species by weight was good. The general ratings for 1968 to 1972 are as follows:

Fish	Ranking by weight of catch in South Atlantic Region
Menhaden	1
Blue crab	2
Shrimp (total)	3
Alewives	4
Thread herring	5

Agreement for the next 10 species was not as conclusive as for the first five. Considerable variations in ranking order existed between states, but the 1969 - 1972 regional averages are as follows (in VIMS, 1974).

Fish	Ranking by weight of catch in the South Atlantic Region
Spot	6
Gray sea trout	7
Spiny lobster	8
Flounders (total)	9
Croaker	10
Mullet	11
King mackeral	12
Blue fish	13
Kingfish	14
Oyster	15

The flatfishes (halibut, flounders, sole, plaice, and yellowtail) are common along the Atlantic Coastline. They bury themselves in unconsolidated sediments. Preferences for specific substrate types are commonly shown by those species (Emery and Uchupi, 1972).

Roundfish or cod, tomcod, haddock, hakes, pollock, and others normally feed on crustacea, worms, mulluscs, and echinoderms which colonize specific types of substrates, thus these species normally are associated with specific bottom types.

The total U. S. commercial fisheries catch for the Central and North Atlantic Regions in 1972 and 1973 were 1,459,579,000 pounds and 1,478,426,000 pounds respectively. This represented a total value of $180,485,000 for 1972 and $220,140,000 for 1973 The top fifteen species (by weight) landed in the Central Atlantic Region in 1968 were as follows:

Fish	Ranking in the Central Atlantic Region
Menhaden	1
Blue crab	2
Surf clam	3
Alewives	4
Oyster	5
Scup	6
Hard clam	7
Yellowtail flounder	8
Whiting	9
Striped bass	10
Blackback flounder	11
Northern lobster	12
Fluke flounder	13
Soft clam	14
Sea scallop	15

The above data does not reflect the actual dollar value of species catch (URI, 1974).

Fish normally found in open waters include the bluefish, Atlantic mackeral, Atlantic menhaden, and the black bass. Anadromous (those species which swim into the estuaries to spawn) species which are normally found in offshore waters include the alewife and shad. Species of fish which inhabit both the offshore and estuarine waters include the striped bass, summer flounder, scup, weakfish, red drum, striped mullet, and tautog. Species which normally inhabit the estuarine areas throughout the year include the Atlantic croaker and the white perch.

The Continental Shelf widens north of Delaware Bay and extends seaward to encompass Georges Bank and Brown Bank. Two distinct areas can be distinguished by salinity and water temperature. The cooler area of the Gulf of Maine results from rapid vertical water mixing and is characterized by boreal species. The warmer Mid-Atlantic Bight area is dominated by warm water species normally found in the Central Atlantic Region. A total of 196 species have been described as normally occurring within the North Atlantic Region. This figure represents 20% of the total number of species found along the Atlantic Coast (TRIGOM, 1974). The Gulf of Maine contains mostly endemic species while in the Mid-Atlantic Region, a diverse group of southern fishes move north to Cape Cod as spring warming occurs. A cold water barrier at Cape Cod is generated by upwelling between June and September. This area of cold water blocks the northern movement of southern species. During the cooler seasons, several species from the Gulf of Maine may be found on the Mid-Atlantic Shelf, however, fewer species exist in this region during fall and winter than in the summer. The Gulf of Maine remains essentially isothermal throughout the year. The summer southern migrants which move north to Cape Cod include; summer flounder, scup, weakfish, kingfish, mullets, black seabass, filefishes, pompanos, and northern puffers. Some species which move northward around Cape Cod into the Gulf of Maine include the spiny dogfish, silver hake, red hake, white hake, American shad, striped bass, menhaden, bluefish, Atlantic mackeral, butterfish, and bluefin tuna. Species which move southward from the Gulf of Maine along the Mid-Atlantic Bight include; the Atlantic herring, Atlantic cod, and pollock. The major factor involved in these movements is temperature. Fish have definite preferences for certain temperatures. Fish which remain in the Gulf of Maine year around move into deeper waters during the colder months. These fishes move back into shallow water in the spring when the temperatures reach 1.7°C. These species include the eelpout, sculpin, little skate, and winter flounder (TRIGOM, 1974).

Fisheries investigations offshore (15 to 200 meters) have indicated that a total of 110 species normally can be found in the North Atlantic Region. The dominant species off western Nova Scotia include haddock, Atlantic cod, pollock and spiny dogfish. A total of 67 species were caught in the Gulf of Maine. The dominant species were redfish, haddock, spiny dogfish, thorny skate, Atlantic cod, silver hake, pollock and American plaice. Of the 68 species taken on Georges Bank, the following were dominant; Atlantic cod, yellowtail flounder, winter skate, little skate, and eelpout. The principal species on the Mid-Atlantic Bight include: spiny dogfish, yellowtail flounder, red hake, silver hake, little skate and eelpout (TRIGOM, 1974) Clark el al. (1969) estimated that 60 - 70% of the commercially important Atlantic species utilize the estuaries during some period of their lifetime.

The plankton of the estuarine and nearshore areas may seasonally be comprised of significant numbers of meroplankton. The length of time the eggs and larvae of a fish remains planktonic depends upon the species of the organism and the water temperature. The colder the water temperature, the longer the planktonic phase. The importantance of survival through the planktonic stage is generally understood (TRIGOM, 1974). Survival through the planktonic phase has important bearing on the success of the year class as a whole.

Whales, dolphins and porpoises constitute the majority of marine mammals which have been reported along the South Atlantic Region. Occasionally manatees have been observed in the coastal waters of this region. No whales or porpoises are taken along the Atlantic as a result of the U. S. Marine Mammal Protection Act

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of 1972. The Atlantic bottlenosed dolphin and the Atlantic spotted dolphin have been captured for display and research. Seals and sea lions have been rarely reported. Most data on nearshore sightings of marine mammals constitute the presence of stranded, sick, or injured animals and thus give an erroneous indication of species distributions and populations. Thirty-six species of marine mammals have been reported in the Central Atlantic Region. The population of the harbor seal has been estimated at 400,000 in the subartic and temperate waters of the northern hemisphere (URI, 1974). A small population of gray seals have consistantly hauled out near Nantucket. Other seals and the manatee have been rarely sighted in the Mid-Atlantic Region. Whales are regularly sighted in the Mid-Atlantic Region as are porpoises and dolphins but confirmed identification is difficult. Insufficient data exist to allow discussion of cetacean population levels in the area.

The harbor seal is a resident in the North Atlantic Region year around. The gray seal is a relatively common transient in this region. Eight species of cetacean (whales and porpoises) have been regularly reported in the Gulf of Maine (TRIGOM, 1974). Another eight species have rarely been reported and are considered strays. In general little is known about the occurrences and life histories of cetaceans along the entire Atlantic Coast. Only trained observers can distinguish between species of many of the whales and porpoises.

(5) Birds

Data pertaining to oceanic birds which frequent the Atlantic Coastline are incomplete, precluding all but a surficial discussion. Pelagic birds normally found along the South Atlantic Region include: petrels, shearwaters, gannets, phalaropes, jaegers and terns. These birds which migrate through the area annually are part of two groups. The first group moves southward in the fall (gannet, northern and red phalarope, skuas, and jaegars). The second group of migratory birds includes the Wilson's storm petrel which breeds on islands in the South Atlantic and migrate to the North Atlantic (VIMS, 1974). Wilson's storm petrels and shearwaters have been observed in flocks exceeding 10,000 along the South Atlantic Region. Oceanic birds reported in the Central and North Atlantic Regions include the fulmar, shearwaters, petrels, gannets, phalaropes, jaegers, kittiwakes, auk, murres, and the dovekie.

Marine birds feed on fish, plankton, and detritus. Fish-eating birds return nutrients from the water back to shore and are instrumental in recycling nutrients within the surface layer. Feces contain more readily usable forms of nutrients than the food organisms. Sea birds also utilize the shoreline for breeding and the raising of their young. These birds have been faced with the continuing degradation of beach and marsh habitats by the encroachment of man.

(6) Unique Environments

No natural occurrences of rock or other hard substrate along the South Atlantic Region have been reported. Man made structures such as jetties, pilings, sea walls, breakwaters, and artificial shell beds are fairly common in this region however. These substrates are colonized by characteristic organisms which are not found in numbers elsewhere in the region. This also holds true for the southern portion of the Central Atlantic as well.

Zonation, due to degree of exposure above water is evident along intertidal substrates. Barnacles appear in zones which normally are exposed (supralittoral) and those which are normally underwater (intertidal and subtidal) during the tidal cycle. Many tube forming polychaetes, amphipods, limpits, periwinkles and others are also found in this zone. Sponges, anemones, annelids gastropods, pelecypods, decapod and tunicates are dominant in the subtidal area.

Four offshore types of unique bottom assemblages have been described. These are the calico scallop beds, coral outcroppings, relict Lithothamnion reef deposits, and "black rock reefs." Two calico scallop beds have been identified off Cape Canaveral and in Raleigh Bay (VIMS, 1974). A total of 112 species were identified from one dredge in these beds. The dominant species were Argopecten gibbus (the calico scallop), the polychaetes Pamotaceras americanus, *P. caerulus*, *Sabellaria floridensis*, and *Polydora websteri*. Plankton and detritus serve as food sources for this assemblage.

Coral outcroppings have been investigated in Onslow Bay, North Carolina. These outcroppings consist of coral heads (*Solenastera hyades* and *Sidastrea siderea*, *Oculina arbuscula*, *Astrangia astreiformis*, *Phyllangia americana* and *Bolanaphyllia floridana*) (VIMS, 1974). These areas are utilized as food sources by commercial demersal fishes. Eighty nine species of polychaetes and 74 species of molluscs are associated with these coral structures. The order of dominance of species varies from one outcropping to another.

A large (80 nautical mile) reef, formed by ancient *Lithothamnion* deposits have been discovered at the edge of the shelf (VIMS, 1974) One hundred and seventy species from 11 phyla have been identified from this reef. Of these, 62 species were molluscs, 48 arthopods, and 17 annelids. The dominant organisms on the upper reef were the pelecypod *Glycymeris* and epifaunal echinoids, gargonians, hydroids, and bryozoans. The dominant organisms on the lower reef include the gastropod *Polystira* and the crab *Acanthocarpus* (VIMS, 1974). The food web is based upon detritus and plankton from the photic zone above.

Rock outcroppings referred to as "black rock reefs" have been identified off the coast of North Carolina and northward (VIMS, 1974 and URI, 1974). These outcrops consist primarily of Trent marl (fossil remains of the pelecypod *Venus gardneri*). Over 300 species which are normally associated with these outcroppings have been identified. Tube building polychaetes and a sessile snail (*Vermicularia spirota*) are the major species responsible for present reef building. Sessile clams and the boring clams (*Soxicana rugosa* and *Lithophaga bisulcota*)are the most conspicuous organisms in samples of these structures.

Unique benthic organisms occur in the nine submarine canyons located in the Central Atlantic Region. These canyons are characterized by straight V-shaped valleys with unconsolidated motile sediments in the valley floor. Red crab and lobster represent an increasing fishery from the canyons. Rowe (1971) described a sea cucumber (*Ophimusuim bymani*) which characterizes the Hatteras Canyon. The association of several organisms indicates a canyon type assemblage. These species include a sea pen, two seastars, and an anenome. Red crab (*Geryon quinquidens*) have been recovered from exploratory travels from depths of 360 to 960 feet in several of the canyons in this region (URI, 1974). The bottom types in the North Atlantic Region are numerous and varied. Unconsolidated sediments, gravel, silt, and rock are common, creating an area of diverse bottom types.

e. Natural Phenomena Unique to an Area with Potential to Cause or Contribute to Environmental Impacts of Proposed Action (Atlantic)

(1) Winds

The incidences of winds along the Atlantic coastline have been described in the section on climatology. Generally the windiest season is winter. The most severe wind conditions occur during the passage of a hurricane system through the area. Tetra Tech, Inc. (1973) predicted maximum sustained winds for the Atlantic coast, and the probabilities of winds exceeding given speeds on an annual cycle. The probability of a sustained wind exceeding 80 knots is 0.1, for winds in excess of 100 knots as 0.05, and 120 knots as 0.01. Sustained winds in excess of 80 knots may present hazardous operation conditions aboard rigs and supply vessels. Wind generated waves or swells resulting from severe wind conditions will accentuate the hazards involved.

(2) Waves

Wind generated waves have been briefly described in the physical oceanography section. The occurrence of waves in excess of 50 feet constitutes a significant hazard to offshore operations. The reporting of a wave in excess of 100 feet by the USS Ramapo (as described in the section on waves) points out the potential hazards of these occasional waves. Rig designs must incorporate deck clearances, and structural stability to withstand the stresses these waves generate.

Of more serious concern are the stresses set up by much less dramatic but more common smaller waves. Wave period and structure resonance should be considered in rig design as well.

No damaging tsunamis (seismic sea waves) have been reported along the Atlantic coast.

Storm surges have caused extensive damage along the Atlantic coast (see description in the section on physical oceanography). Significant elevations of sea level along low lying coastal areas may impact on support facilities located there.

(3) Icing

As described previously, ice formation is not expected to significantly hamper offshore operations. Ice formation, however, may occur in the northern portions of Georges Banks during the month of February.

(4) Reduced Visibility

The incidence of reduced visibility has been described in the meteorology section. As expected, periods of reduced visibility may reduce efficiency of offshore operations.

(5) Geologic Conditions

Glaciated areas of the north Atlantic shelf are characterized by irregular topography and locally-thick accumulations of unconsolidated bottom sediment. Linear sand swales and ridges occur along virtually the entire East Coast inner shelf, and have been known to migrate over several tens of meters distance during severe storm activity. Portions of the extensive barrier island system extending southward from Long Island to the Carolinas are also vulnerable to significant morphologic change.

2. Gulf of Mexico Region

a. Geology

Geologic History

The Gulf of Mexico is a relatively old geologic feature with a depositional history dating from the Jurassic period or possibly earlier.

Throughout Early and Middle Jurassic time much of the Gulf area was covered by shallow seas in which restricted circulation allowed extensive precipitation of evaporites, chiefly salt and, to a lesser extent, anhydrite. By early Cretaceous time, active organic reef complexes extended over much of the southern and eastern Gulf areas. Reef growth continued throughout the Cretaceous and Tertiary periods and was accompanied in the southeast by slow regional subsidence, so that great thicknesses of shallow carbonate deposits accumulated over the Yucatan-Florida-Bahamas area.

At the end of the Mesozoic, an intense period of mountain building (Laramide Orogeny) elevated the Rocky Mountain in the western United States. Subsequent erosion of this elevated terrain during the Tertiary supplied vast quantities of clastic sediment (sand, silt, clay) to rivers draining into the north-central and northwestern Gulf. These sediments accumulated in the slowly-subsiding Gulf Coast Geosyncline (depositional basin). Continued sedimentation throughout the Cenozoic Era has resulted in a southward progradation of the Gulf coastal plain, while regions of maximum deposition within the basin have migrated northeastward to the present Mississippi River delta area.

The Gulf of Mexico continental margin thus consists of two different geologic provinces--an eastern region of shallow carbonate banks and relatively simple structure, and a western region of primarily land-derived sediments and complex structural regime involving extensive faulting and salt mobilization.

(1) Eastern Gulf of Mexico OCS

(a) General

The continental margin of the eastern Gulf of Mexico represents part of a broad area of shallow-water carbonate and evaporate accumulation that includes also the Yucatan and Bahama platforms to the west and east, respectively.

The broad continental shelf off Florida, known as the West Florida Shelf, varies in width from less than 100 km in the north to more than 250 km in the southwest (Fig. 27). Reef structure and relict shoreline features impart minor topographic relief to the relatively flat shelf. An extensive reef-type complex called Florida Middle Ground covers an area of more than 750 km^2 on the outer shelf northwest of Tampa with topographic relief of up to 18 meters (Bergantino, 1971).

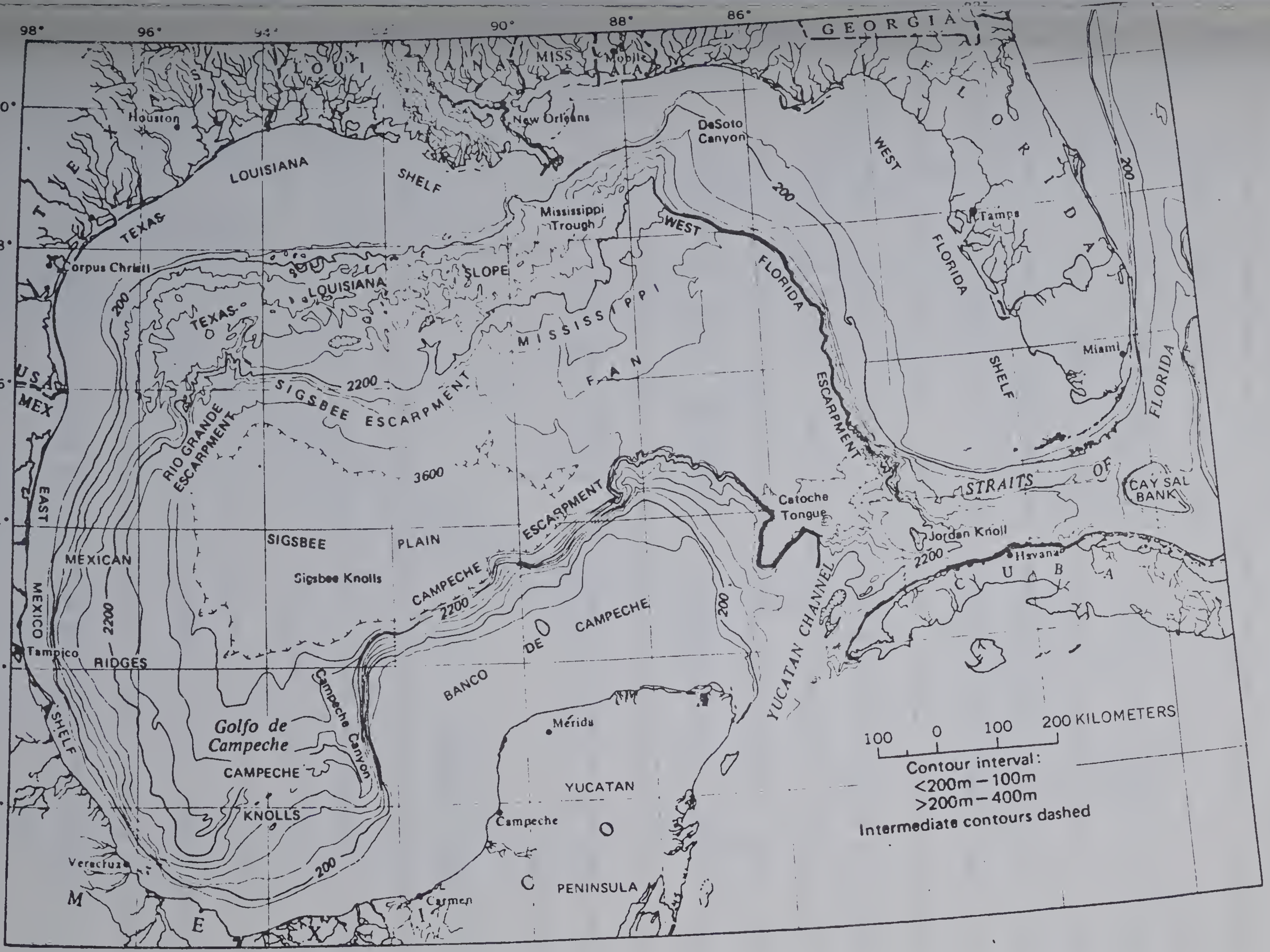


FIGURE 27. Bathymetric map of the Gulf of Mexico showing major physiographic and structural features. Bathymetry adapted from Uchupi (1967). (from Garrison and Martin, 1973).

The West Florida Escarpment lies at the base of the continental slope and forms the western boundary of the continental margin off Florida. The face of the escarpment north of latitude 27°N is relatively smooth and steeply-inclined while the southern segment shows lesser gradients but more complex relief. Rocks dredged from the base of the escarpment indicate this feature orginated as a Lower Cretaceous reef that has since subsided nearly 2.5 km. (Antoine, et al., 1967). To the south, the eastern Gulf continental margin is bordered by the Straits of Florida, while in the north, the boundary consists of an area of lithologic and structural transition joining the eastern Gulf carbonate province to the western Gulf clastic province. The DeSoto Canyon, a submarine feature within this transition zone, is usually taken as the physiographic boundary between the eastern and western Gulf geologic provinces.

Subsurface Geology

Geophysical surveying and onshore drill data have revealed a southward-thickening section of Mesozoic-Cenozoic shallow-water carbonate and evaporite strata beneath the Florida Platform (Fig. 28). The thick southern sequence accumulated in a subsiding depositional trough (South Florida Embayment) which extended over much of the southern Florida shelf and eastward to the Bahamas. In the more slowly-subsiding northern area of the peninsula, shallow marine

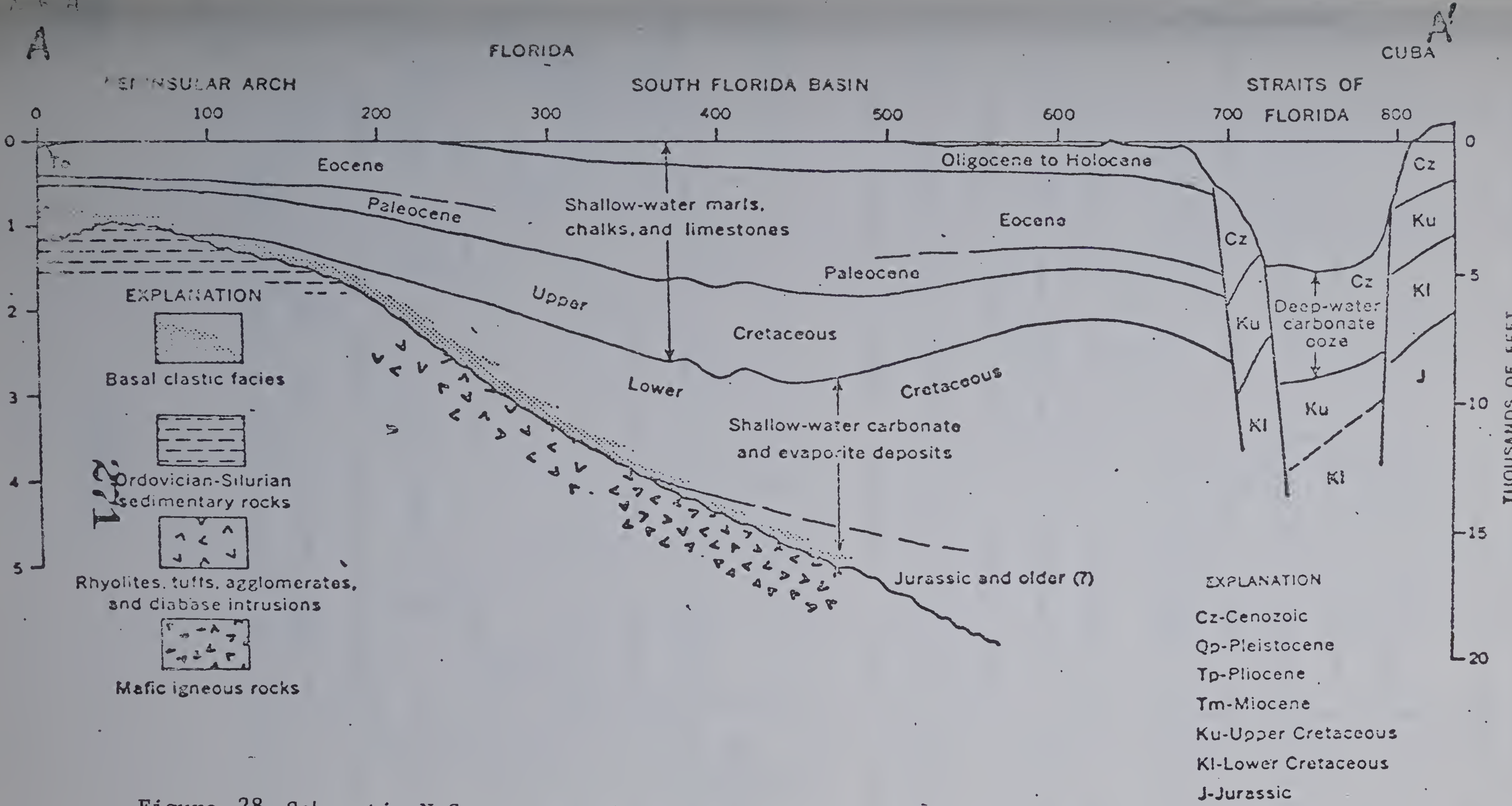


Figure 28. Schematic N-S cross section of eastern Gulf of Mexico (from Martin and Case, in press, A.A.P.G.)

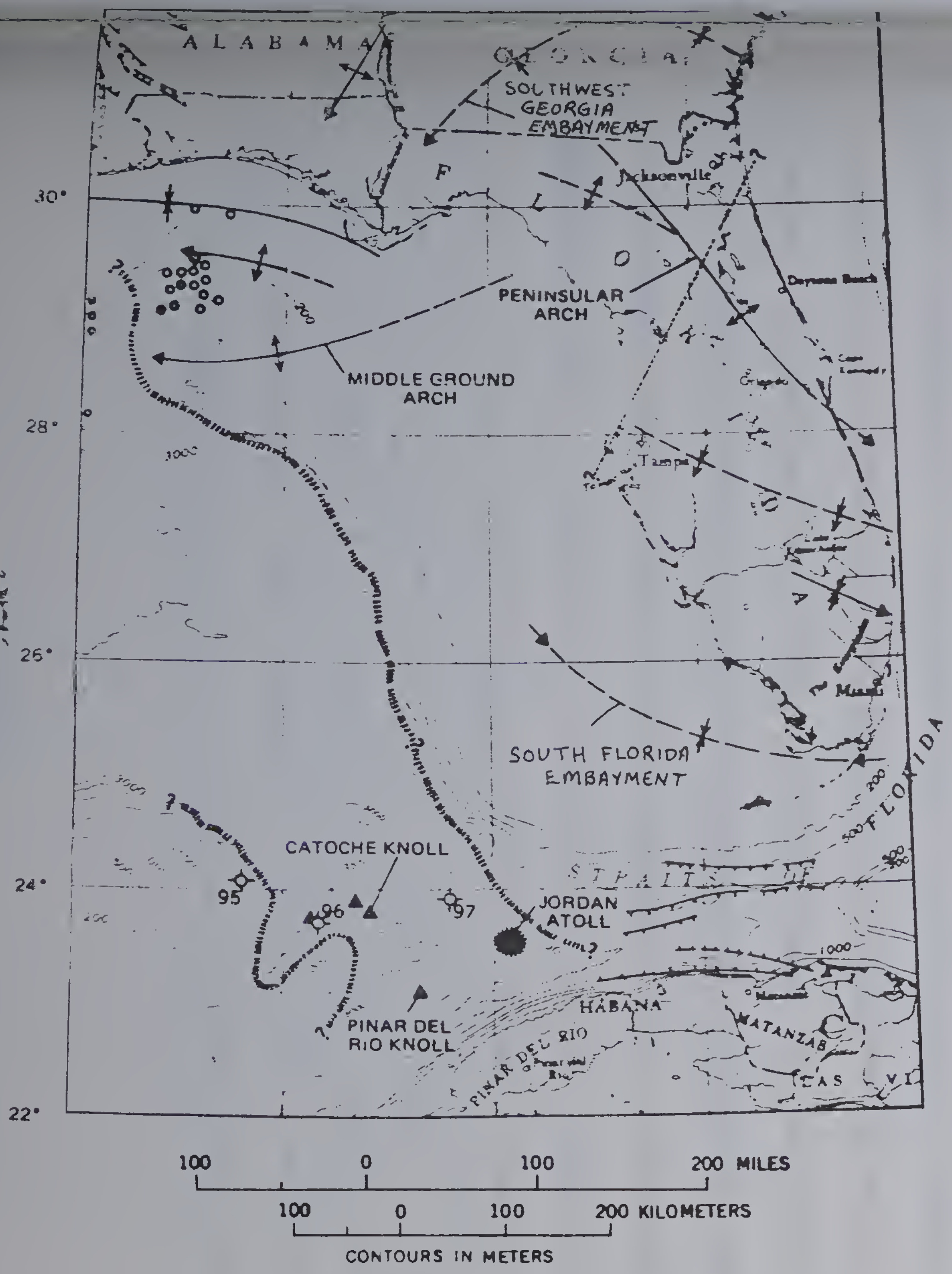
deposits are mixed with non-marine clastic material derived from emergent areas further north.

The major positive subsurface structural feature in the region is the NW-SE trending Peninsula arch, which existed as a topographic high during Early Cretaceous and early Late Cretaceous time. An auxilliary structure, the Ocala uplift, extends from the Peninsula Arch towards the Gulf (Fig. 29).

The Southwest Georgia Embayment, extends across the northeastern Florida Panhandle into southern Georgia and Alabama. While onshore wells in this area have revealed a Cretaceous-Miocene sedimentary rock section almost 9000 feet thick (Rainwater, 1971), Maher (1971) estimates the thickness of the offshore section may exceed 15,000 feet.

Bottom Sediments

The unconsolidated sediment cover of the eastern Gulf continental shelf areas is discontinous and thin, representing in large part, relict deposits which date from the last major marine transgression (rise in sea level) that occurred during late Wisconsin time. Sediments of the west Florida shelf grade seaward from relict, nearshore quartz sands through zones dominated by shells and shell fragments, algal and peletoid (oolitic) organic sands to biogenic silts and oozes on the outer shelf and slope (Gould and Stewart, 1955). Shelf sands along the Mississippi-Alabama coastline



EXPLANATION

ANTICLINAL AXIS – Axis of open fold or arch showing direction of plunge; mainly basement rocks, dashed where inferred

SYNCLINAL AXIS – Axis of large fold or embayment showing direction of plunge; many of these involve basement rocks, dashed where inferred

MONOCLINE

THRUST FAULT – Sawteeth on overthrust side

NORMAL FAULT – Hachures on downthrown side

CONCEALED FAULT – Involves basement surface only

BARRIER REEF – Approximate trend of Lower Cretaceous reef revealed by seismic-reflection profiles and bottom samples in eastern Gulf of Mexico, and by geophysical data and drilling in Mexico

● ○ SALT DOMES – Diapiric structures known or inferred to be formed by evaporites. Dot indicates domes in which salt or caprock has been reached by drilling; open circle denotes diapirs revealed by seismic-reflection profiling. The apparent linear distribution in places reflects the ship's track

▲ IGNEOUS INTRUSION – Pluglike mass interpreted from geophysical data to be of igneous origin

3◇ DRILL HOLE – Location and number of JOIDES Deep Sea Drilling Project site

Figure 29. Principal structural elements and trends of the eastern Gulf of Mexico and adjacent coastal plain (after Garrison and Martin, 1973).

extend up to 50 miles (80 km) offshore, and to water depths exceeding 55 meters (Brooks, 1973).

(b) Hydrocarbon Potential

Since few wells have been drilled in the eastern Gulf of Mexico, little is known of the actual hydrocarbon potential of this area. Some measure may be gained through inference from onshore geology and producing trends and interpretation of offshore seismic data, although these estimates are highly speculative.

There has been significant production from the onshore Mississippi-Alabama-Florida area. Numerous fields have been in operation since 1939. At least 133 fields have been discovered with Mesozoic production. In addition, there are 23 Mesozoic fields in Alabama and three in the northern Florida Panhandle. Production is mostly centered in the eastward extension of the Mississippi Salt Basin, a structure that contains shallow salt domes (as shallow as 410 feet) and has a large potential for hydrocarbon production (Braunstein, 1958). Alabama fields are smaller than those in Mississippi, but are also located on the margin of the Mississippi Salt Basin. The most productive zones in these states are the lower and upper Cretaceous formation including the Tuscaloosa, Eutaw, Paluxy, and Glen Rose formations, all of which are sands (Rainwater, 1970; Paine and Meyerhoff, 1970; and Braunstein, 1958). Production in Florida is limited to two areas, although several hundred wells have been drilled. The Jay field, located in Santa Rosa County in the panhandle was discovered in 1970, and is producing from the Jurassic Smackover formation which is a very prolific limestone at onshore locations.

Four fields are active in South Florida, the largest of which is the Sunniland Field. All of these fields are in the lower Cretaceous Sunniland limestone, and are part of the thick shale and carbonate sequence of the South Florida Embayment. There is some promise for large fields in this trend which is continuous onto the continental shelf of West Florida. Stratigraphic and reef traps are the most likely types of oil reservoirs, although some structural traps may be present and are potential producers.

The upper Jurassic and lower Cretaceous rocks are most prospective for oil and gas. Production is anticipated from the Smackover limestone and possibly from sandstone reservoirs in the Jurassic. It is also anticipated from carbonate rocks in the lower Cretaceous, although some sandstone interbeds are anticipated just south of the Florida Panhandle.

Upper Cretaceous and Tertiary rocks are not considered as prospective with the possible exception of the lower Tuscalossa sandstone in the northernmost part of the area, and perhaps some Paleocene reefs elsewhere.

One structure is of particular interest in this area. South of Choctawhatchee Bay is the large Destin Anticline, a 20 by 50 mile structure in the upper Jurassic-lower Cretaceous strata. The long axis of the anticline is oriented east-west and is located approximately 40 miles south of the beach. It has nearly 3,000 feet of closure (more or less the "height" of the structure) and is comparable in size to some of the great producing structures of the Middle East (U.S. Geological Survey Seismic Reflection Data).

Farther south on the West Florida shelf, there is abundant evidence of reefs of probable lower Cretaceous age. There is a strong possibility that production could occur from these reef structures and from the seaward continuations of the thick sequence of strata in the South Florida Embayment.

(c) Geologic Hazards

The Eastern Gulf shelf is a seismally stable geologic area, having shown little earthquake activity for at least the last two hundred years. The coastal areas of Mississippi, Alabama and western Florida are nearly as stable, with only one historic seismic event (1955, Gulfport, Miss., intensity V). Further inland, two earthquakes (1879, 1900) of moderate severity (V-VI) occurred in northeastern Florida along the St. John's River Fault Zone. As a consequence of this distribution of seismicity, nearly all of the Eastern Gulf of Mexico coastal regions lie in seismic risk zone 0 (Algermissen, 1969), indicating no reasonable expectancy of earthquake damage. Because of the geological similarity of coastal areas of the Eastern Gulf to adjacent areas of the continental shelf, these seismic risk determinations may be extended some distance offshore.

Parts of the West Florida shelf (Big Bend area) are characterized by a submerged karst 1/ topography. In addition, cavernous limestone strata have been identified at the base of the Eocene. While irregular bottom topography can be delineated prior to rig placement, a potential lost circulation zone may not be recognizable prior to drilling. The problem of lost circulation has been encountered many times during drilling operations in other geographic areas, however, so that adequate procedures have been developed to safely handle its occurrence.

Many wells penetrating Mesozoic rocks in Mississippi have encountered abnormally high formation pressures. The extent of these Mesozoic geopressures in other onshore and offshore areas is not known, although they were not encountered in Smackover (Jurassic) strata during development of the Jay field on the Florida Peninsula.

1/ Carbonate rocks are prone to dissolution by circulating water, e.g., rivers or subsurface groundwater, so that geographic areas characterized by sufficient rainfall, extensive limestone strata and active subsurface runoff, commonly develop a system of underground channels, caverns and nearsurface sinkholes. The term, Karst topography is derived from such a region--the Karst district on the eastern coast of the Adriatic Sea.

(2) Central and Western Gulf of Mexico OCS

(a) General

Much of the lithologic and structural characte of the Western Gulf of Mexico can be related to the thick clastic sedimentary sequence which accumulated in the Gulf Coast Geosyncline during the Cenozoic Era and the extensive Jurassic evaporite deposits that underlie much of this Cenozoic section.

Gulf Coast Geosyncline (Gulf Coast Basin)

The Gulf Coast Geosyncline is a broad depositional trough that extends over much of the western Gulf continental margin and adjacent land areas. Onshore, to the north and west, the structural basin and its sedimentary deposits form the emergent Gulf Coastal Plain, the physiographic unit which borders the Gulf of Mexico and the southern States of the United States. The continental shelf is the underwater extension of this generally smooth, gently-dipping coastal plain. The shelf offshore Texas and Louisiana ranges in width from 60 miles (97 km) on the west to 160 miles (257 km) off the Texas-Louisiana border. The continental slope of the northwestern Gulf marks the seaward extent or growth margin of the Geosyncline. This slope consists of two segments; a broad upper slope with shallow, 1-2° declivities and irregular relief and a relative steep lower slope which breaks off abruptly along the Sigsbee and Rio Grande Escarpments.

In existence since at least the Mesozoic Era, the Gulf Coast basin has received Cenozoic sedimentary deposits which amount to more than 50,000 feet in total thickness (Fig. 30). These Cenozoic deposits are predominantly clastics (sands, silts, and clays), derived from land areas to the north and west and carried into the basin by major rivers draining into the Gulf of Mexico. The great majority of these deposits represent the coalescing, overlapping deltas of rivers which repeatedly shifted their courses throughout the Cenozoic. Near the seaward margins of these ancient deltas, deltaic deposits grade into, and interfinger with marine shales and clays. Deposition in the basin has been almost continuous throughout the Cenozoic era, with slow, general subsidence of the basin flow keeping approximate pace with the rate at which the sediments accumulated. The result has been partial filling of the Gulf Coast basin with a thick prograding sedimentary rock wedge which pinches out updip towards the margins of the basin and thickens seaward (Fig. 31).

Structure

Offshore Louisiana, in spite of the subsidence which has taken place in the Gulf Coast Basin beneath it, is a stable area of relatively simple tectonics. Its most prominent structural anomalies are salt domes and a series of regional, down-to-the-Gulf faults which have

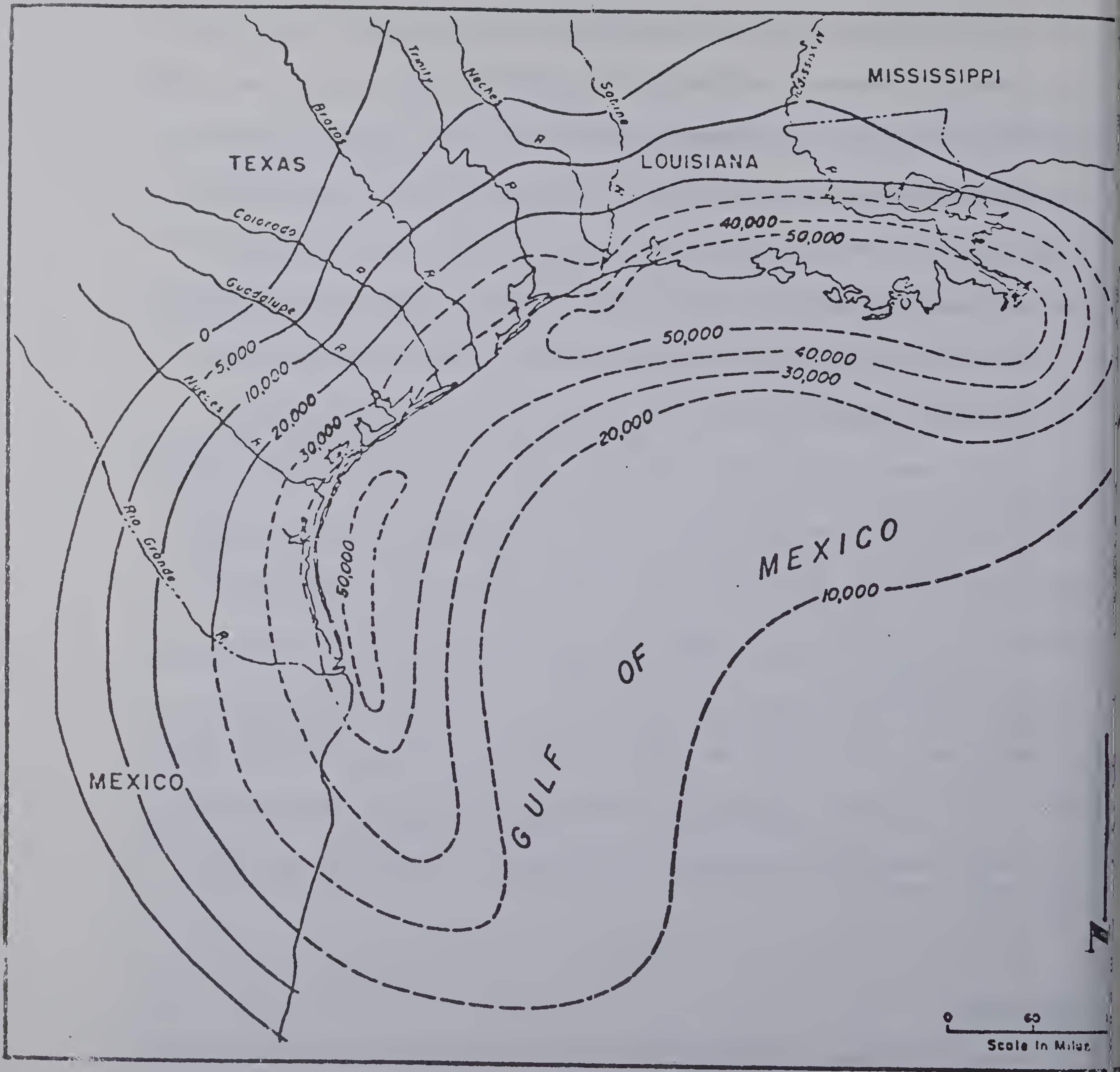
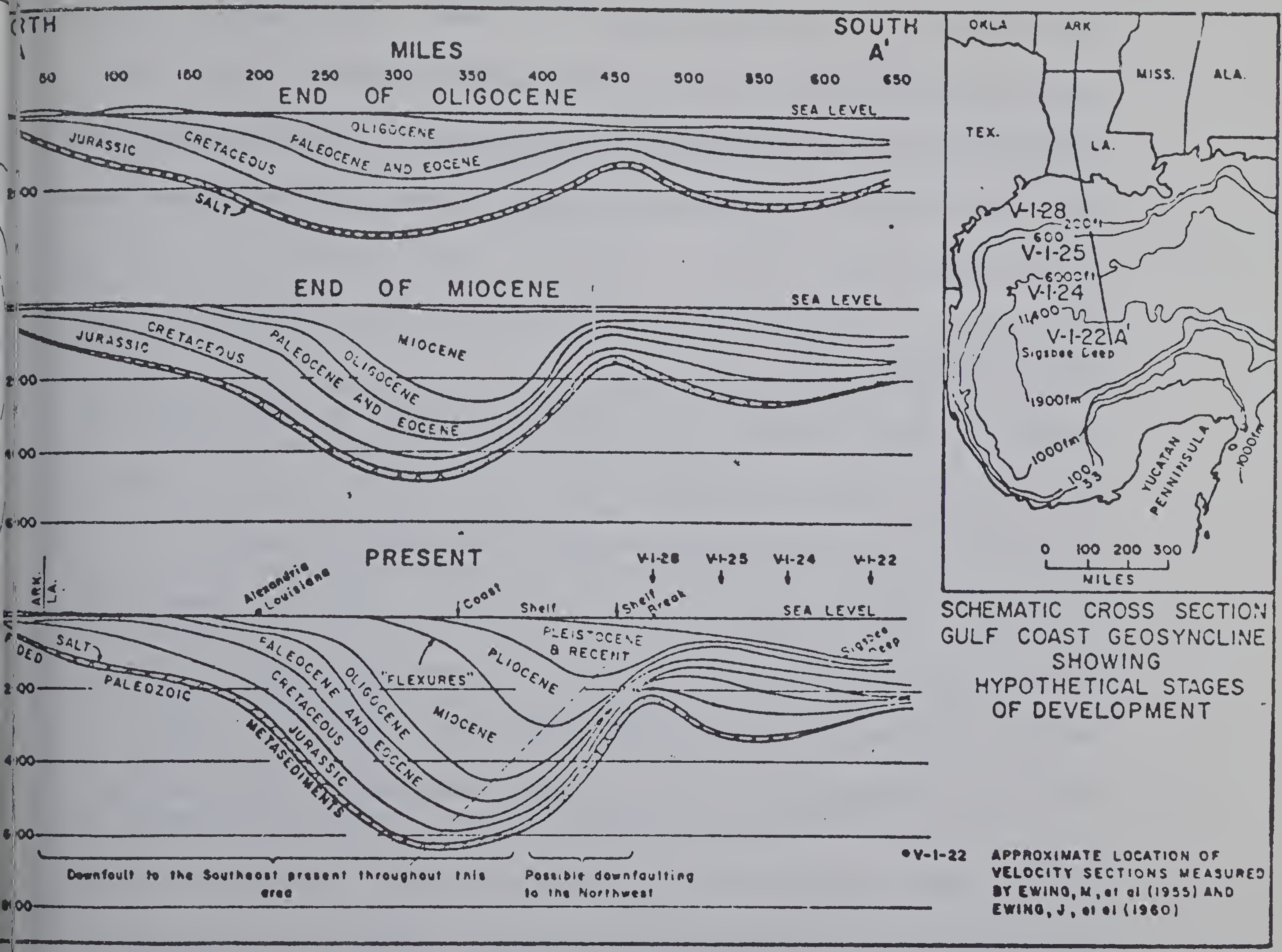


Figure 30. Map showing generalized thickness of Cenozoic sediments in the Gulf Coast Geosyncline (From Hardin, 1962). Isopachs in feet.



These sections represent hypothetical stages in the development of the Gulf Coast geosyncline. The area of greatest subsidence moved progressively seaward as the location of the greatest thickness of sediments deposited during each unit of time moved seaward.

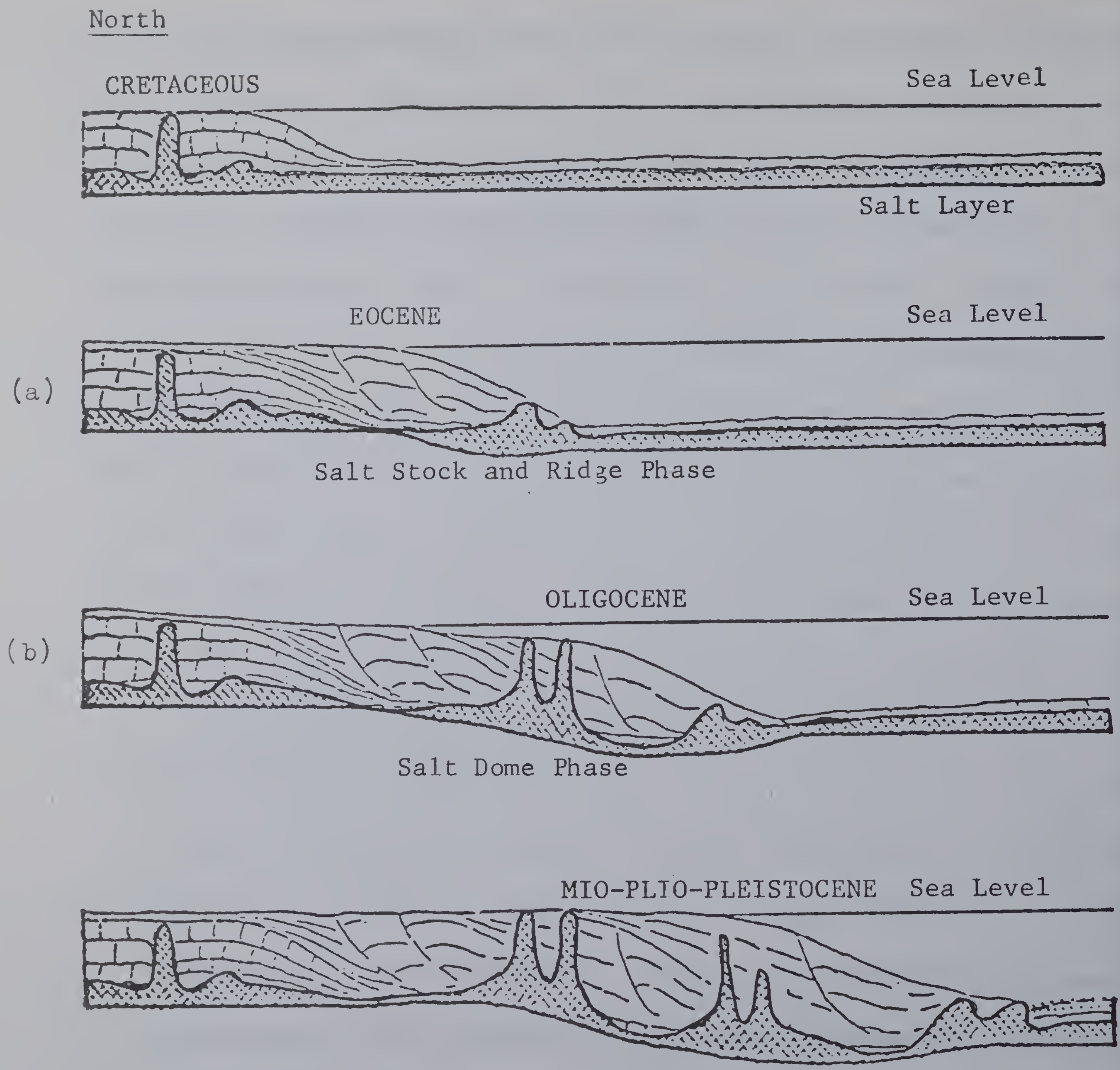
Figure 31 . Schematic cross sections showing development of the Gulf Coast basin (from Boykin, 1972).

materially affected sedimentation across them. Less common are deep-seated, low-relief uplifts and shale domes or ridges. These structural features are related to the presence of an underlying salt basin and the Cenozoic sedimentary wedge which has gradually advanced seaward across it.

Salt Structures

Beneath the north-central and northwestern Gulf, the thick layer of salt laid down over 100 million years ago has been slowly deformed and mobilized by the excessive weight of prograding Cenozoic sediments. In areas of sufficient overburden, the lower density of the salt (2.2 g/cm^3 vs. 2.5-2.6 g/cm^3 for overlying consolidated sediment thicknesses exceeding 2000 feet) has caused it to rise buoyantly, upwarping and, in many cases, penetrating the overlying strata.

The processes of differential loading and plastic flow within the salt beds of the northern Gulf are believed to have been initiated at the front of the advancing sedimentary wedge. Underwater depositional fans, formed at the mouths of submarine canyons eroded into the continental slope, were built up above the nearly-flat abyssal plain, where only a thin layer of sediments covered flat-lying beds of the salt basin. Plastic flowage induced in the salt by the weight of the sediments in the overlying fans moved salt outwards from beneath them. Rates at which the salt flowed outwards evidently exceeded the rates at which new sediments were added to the fans, so that the eventual result was the conversion of the fans from topographic highs into topographic lows. The new depressions continued to localize sedimentation within them and, in turn, the outward movement of salt continued. Outward lateral growth of these depressions, as sediments continued to move down the submarine canyons and into them,first divided the flat-topped salt mass into salt plateaus and intervening topographic lows. Continuing enlargement and eventual coalescence of the sediment-trapping depressions, accompanied by further squeezing-out of the salt from beneath them, led to dissection of the intervening salt plateaus, first into peripheral ridges and later into elongate ridge segments and individual broad salt masses. This latter stage is thought to be the stage of development reached beneath the upper part of the present continental slope, accounting for its chaotic, hummocky topography. Salt domes, as such, are products of a later stage, beginning only after the growing continental shelf has advanced outwards across the salt structures of the former continental slope (Fig.32). The same processes of differential loading, now manifested by greater deposition within the old sediment-trapping depressions than across the salt highs, continued the further depression of the lows and the concomitant lifting of the highs. During this continental-shelf stage, upward salt influx occurs



a) Lateral displacement of salt under differential loading pressure from prograding sediments; growth of salt stocks and ridges

b) Growth of salt domes and diapirs from salt stocks and ridges.

Figure 32. Suggested development of salt structures in the Gulf Coast basin (modified from Wilhelm and Ewing, 1972).

from the outer flanks of the original salt ridges and salt masses. The process operates to reduce cross-sectional areas of these salt bodies and to uplift them; it continues until flanks of the developing salt dome have become almost vertical.

Piercement salt domes (diapirs) are associated with the continental-shelf stage. These are salt spines which grow upward from an underlying, larger salt mass. Typically, they 'break' through the sedimentary-rock cover above them, carrying upward a sedimentary "lid" which is bounded by high-angle faults. The bounding faults radiate outwards from the salt core or, sometimes, are "trap-door" faults which lie tangent to a part of the salt dome. Salt domes probably 'break' through only once, responding to further pulses of uplift by movement along the pre-existing bounding faults without actually intruding the overlying rocks. Final stages of the growth of a salt dome result in the warping of the overlying beds into a gentle dome above the salt plug. A second set of faults, "stretch" faults which result from this 'stretching' of the overlying beds, is formed during this closing stage of salt-dome growth. Figure33 shows major structural features and the regional distribution of diapric structures within the Western Gulf of Mexico.

A series of regional faults is present in the Texas-Louisiana subsurface, in alinements approximately parallel to the coast.

EXPLANATION (Figure 33).

///	ANTICLINES – Elongate, closely spaced, and mainly involving only sediments and sedimentary rocks in Mexico and western Gulf; metamorphic rocks in Yucatan Channel. Submerged areas are diagrammatic in part
—┼→	ANTICLINAL AXIS – Axis of open fold or arch showing direction of plunge; mainly involving basement rocks, dashed where inferred
—┼→	SYNCLINAL AXIS – Axis of large fold or embayment showing direction of plunge; many of these involve basement rocks; dashed where inferred
-┼-	DOME
▲▲▲	THRUST FAULT – Sawteeth on overthrust side
┴┴┴	NORMAL FAULT – Hachures on downthrown side
…………	CONCEALED FAULT – Involves basement surface only
||||||	BARRIER REEF – Approximate trend of Lower Cretaceous reef revealed by seismic-reflection profiles and bottom samples in eastern Gulf of Mexico, and by geophysical data and drilling in Mexico
● ○	SALT DOMES – Diapiric structures known or inferred to be formed by evaporites. Dot indicates domes in which salt or caprock has been reached by drilling; open circle denotes diapirs revealed by seismic-reflection profiling. The apparent linear distribution in places reflects the ship's track
▲▲▲	SALT FRONT -- Leading edge of salt mass where lateral as well as upward movement is inferred. Humps on evaporite side
1 ◇	DRILL HOLE -- Location and number of JOIDES Deep Sea Drilling Project site
—·—·—	INNER MARGIN OF COASTAL PLAIN
- - - -	EDGE OF DIAPIRIC PROVINCE - Mappable boundary of diapiric structures, as shown by seismic reflection profiles in the Sigsbee Plain

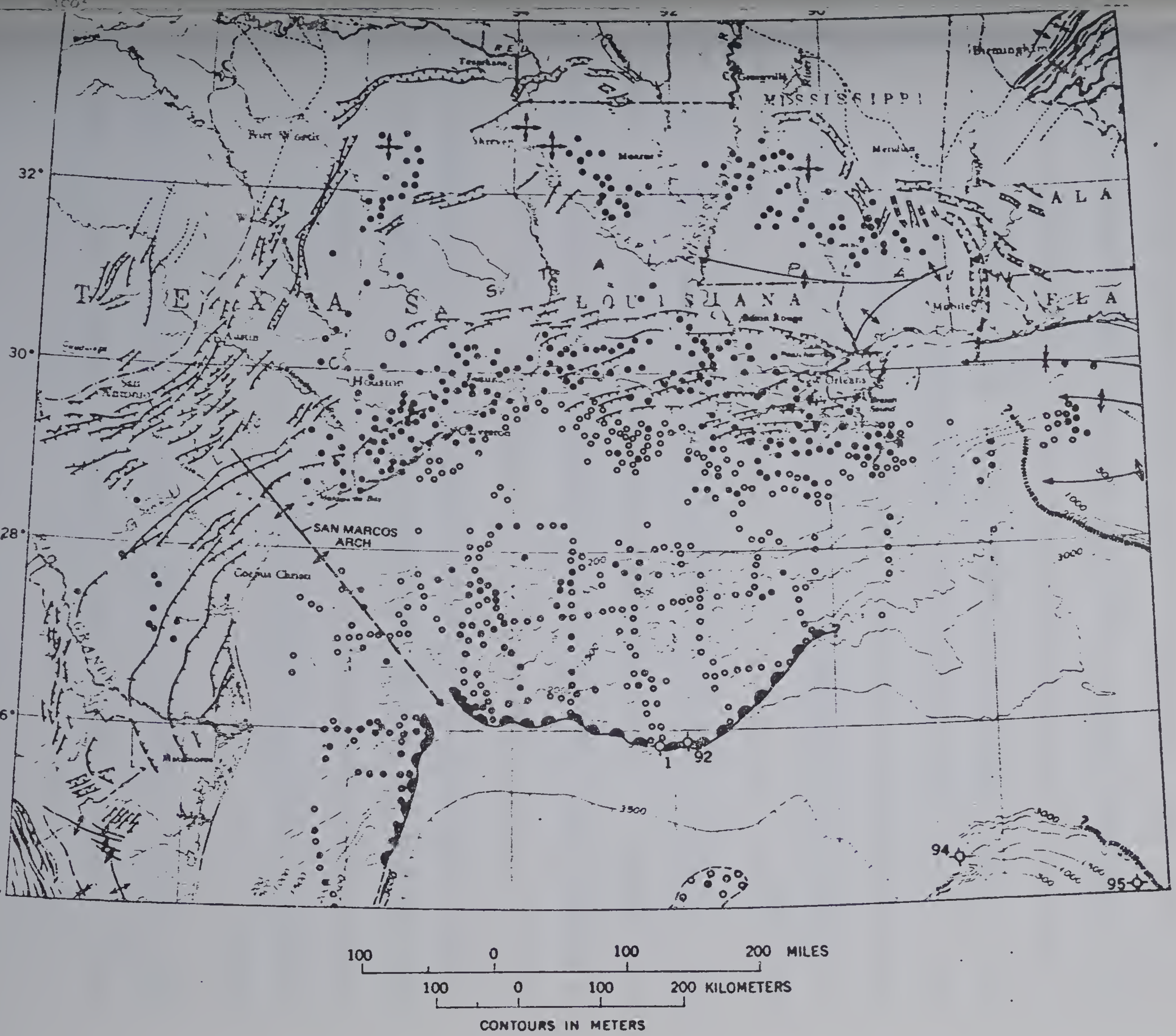


Figure 33 . Principal structural elements and trends of the northwestern Gulf of Mexico and adjacent coastal plain (from Garrison and Martin, 1973).

These are always 'normal' faults 1/, long and arcuate in horizontal plan, with large amounts of vertical displacement downwards into the coastal basin. Rock units commonly show greater thicknesses on the downthrown sides of these faults, and the name "growth faults" is often applied to them (and to other, more localized faults which show the same pattern of thickening in rock units on their downthrown sides). As the term "growth fault" suggests, fault movement and deposition must have been essentially contemporaneous, with the downthrown section acting as a topographic depression for localized deposition.

Going seawards, each successive fault is progressively younger than the preceding one. Distributional characteristics like these, plus the general shape and form of these features, suggest their probable origin--as gravity slumps (underwater landslides) which have occurred periodically and repeatedly at the seaward (continental slope) edge of the growing sedimentary wedge. Water-logged, fine-grained sediments on transition slopes near the end of growing deltas must have been the sediments involved in this gravity slumping.

Sedimentation on the Gulf of Mexico has been complicated by transgression and regression of the shoreline in response to changes in

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1/ Faults in which the fault block that lies above the inclined fault plane appears to have moved downwards relative to the block below the fault plane.

sea level and/or tectonic movement of the adjacent land mass or sea bed. The overall pattern of deposition is one of regression interrupted by minor transgressions. The result of this is a sequence of continental, deltaic or paralic, and shallow-water sandstones, siltstones, and shales being progressively built-out over marine deposits. At various times in the geologic past, particularly in the Late Tertiary, sea level has been lowered or raised in response to increased or decreased glaciation of the polar regions. This has tended to upset the normal progradation of the shoreline, but at the same time it created extensive salt marsh areas on the now submerged continental shelf. Decay of buried vegetative matter from brackish water marshes is thought to be the primary source of the hydrocarbons found in continental shelf deposits.

The Mississippi Fan dominates the north-central Gulf region. This thick accumulation of primarily Quaternary alluvium extends over a 160,000 square km. area including parts of the shelf, slope, rise and abyssal floor. Bottom gradients range from 2° near the apex to about 0°3' at the outer margin more than 400 miles to the southeast. Within this slope regime, the greatest change in gradient occurs roughly at the 2700 meter isobath, and arbitrarily divides the fan into upper and lower segments (Huang and Goodell, 1970).

Historically, the site of active deltaic buildup along the Louisiana coast has shifted several times during the past million years. Kolb and Van Lopik (1966) identified at least seven sub-deltas of the Mississippi delta-complex. The river's modern 'birdsfoot' delta, the Balaize lobe, extends underwater almost to the continental slope, and represents the uppermost part of the Mississippi fan.

In western areas of the Gulf, surface sediments are generally thin, thickening only near the mouth of rivers. The Holocene sediment cover is unconsolidated and discontinuous over much of the Texas shelf. These deposits are primarily silty clays with sand zones nearshore, while some sizable areas of shell and silt occur also, particularly off Padre Island. From Port Aransas to the Texas-Louisiana boundary the sediment zones become more varied with longer zones of sand and shell with less silt and clay present. Sediment deposits in the southern area have the unique characteristic of alternating bands of coarse and fine sediments paralleling the coast (Curray, 1960). The coarse sediments are presumed to be relict shallow-water deposits whereas the finer sediments represent Holocene shelf deposits (Figure 34).

Tropical storms in the western Gulf have historically redistributed large volumes of unconsolidated bottom sediments, and have altered the morphology of the extensive barrier island system that parallels the Texas coast.

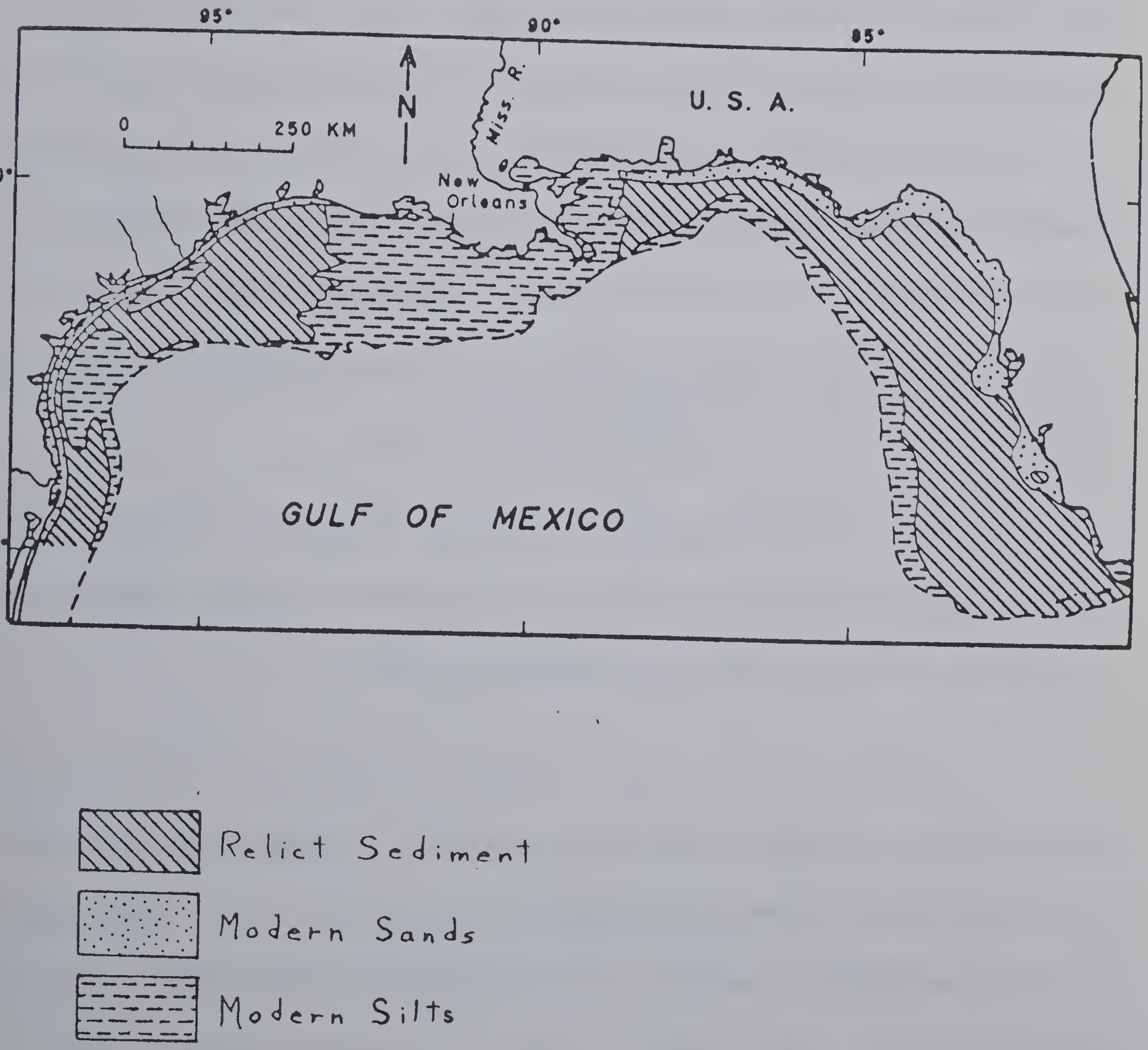


Figure 34. Sediments of the continental shelves in the northern Gulf of Mexico (from Emery, 1968).

(b) Hydrocarbon Potential

The environment of sediment deposition is most significant in its relation to oil and gas production. Sediments deposited on the outer shelf and upper slope have the greatest potential for bearing hydrocarbons for the following reasons:

1) This is the location where coarser, nearshore sands interfinger with the organic-rich marine shales, thus providing an optimum ratio of sandstone to shale. The shale forms the source-rock which provides the oil and gas and the sandstone provides the reservoir into which the hydrocarbons migrate.

2) In this environment, the organic material deposited with the fine-grained clays and muds is preserved, and not oxidized as it might be in shallower, more turbulent water.

3) At this location, the increased overburden of the prograding shallow marine deposits over the plastic salt and marine shales initiates salt flow which triggers the growth of salt domes and regional expansion faults, thus providing potential traps for the hydrocarbons.

This environment, therefore, is the optimum one for providing the three ingredients necessary for the successful formation and accumulation of oil and gas--reservoir rock, source beds, and traps. Environments seaward of the outer shelf-upper slope have progressively less sand to act as reservoirs, and landward environments have progressively less source material, i.e., organic material.

During the Miocene, Pliocene, and Pleistocene, large volumes of sediment derived from the Mississippi River system were supplied to the offshore Louisiana area. The Texas shelf, at the same time, received smaller volumes of sediment because it was on the western border of the Mississippi River depocenter.

Since natural production of oil and gas frequently occurs along the continental shelf-slope break, the progradation of the north-central Gulf depositional regime has resulted in the migration of this production zone seaward, developing a series of progressively younger bands or trends. Figure 35 shows the late Tertiary and Quaternary production trends which underlie the Western Gulf OCS.

There are approximately 366 fields on the Federal OCS of the Gulf of Mexico. Of these 232 primarily produce gas and 94 primarily produce oil. Production depths range from about 1,000 feet to 20,000 feet, and most production occurs between 8,000 and 12,000 feet. USGS records show that 3.152 billion barrels of oil and condensate and 19.8 trillion cubic feet of gas have been produced from Federal OCS lands as of October 1973.

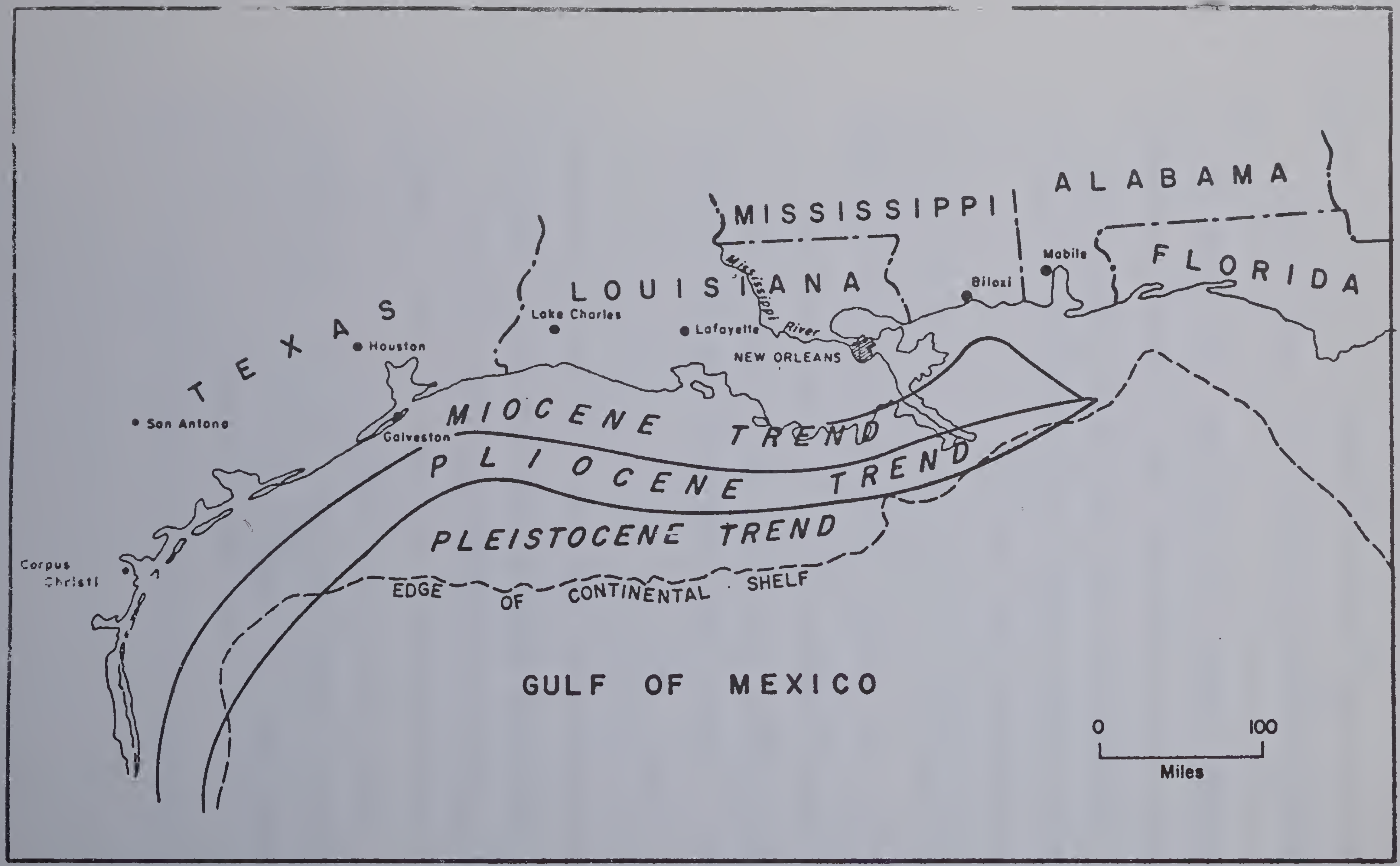


Figure 35. Productive "trends", offshore Louisiana and Texas.

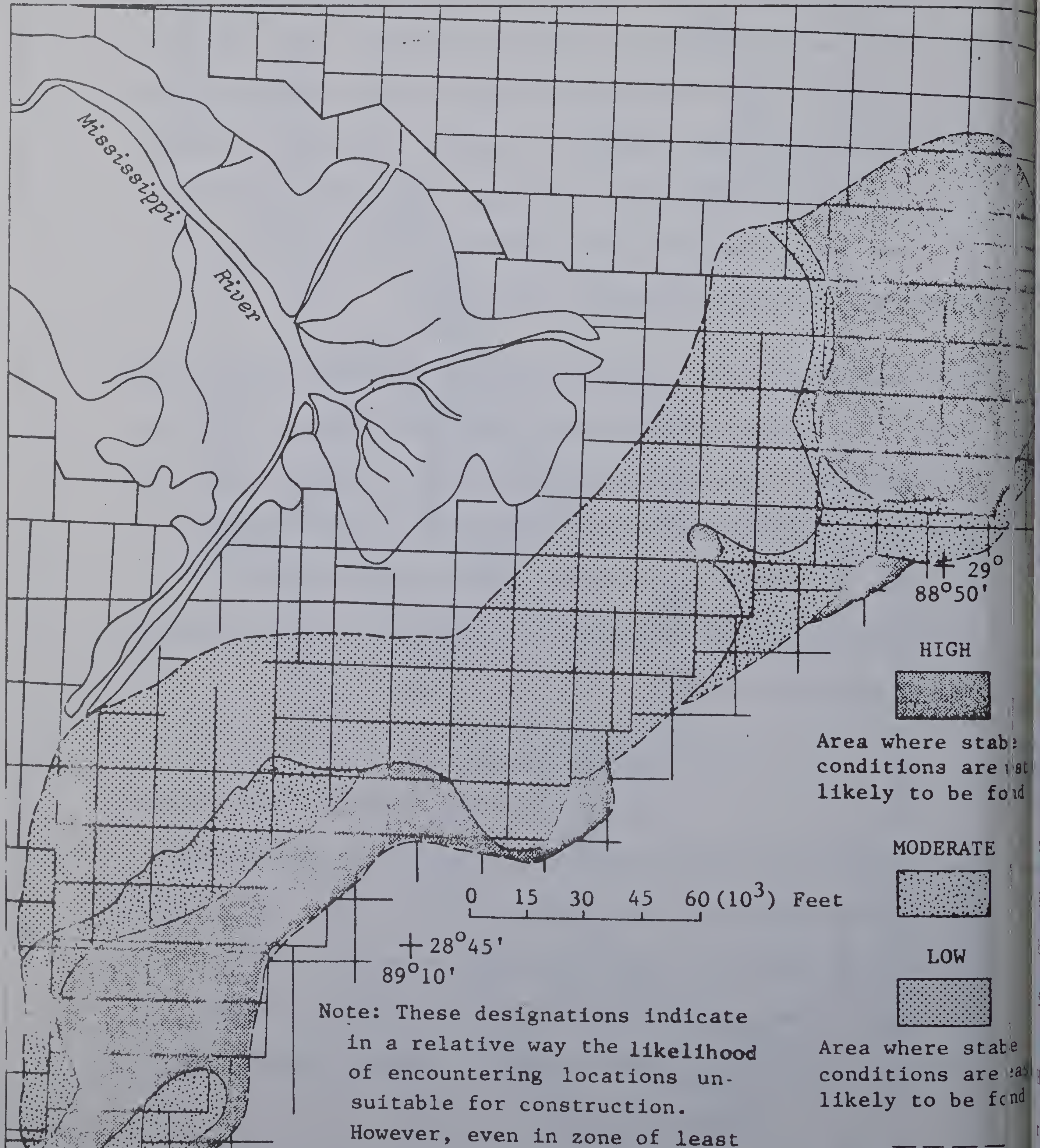
The most prolific offshore production comes from the Miocene of the eastern Louisiana OCS. This area, as currently defined, has more oil than the remainder of the Texas-Louisiana area. The next most productive trend is the Pliocene trend of the central Louisiana OCS which produces about 50%-50% oil and gas. Farther to the west this trend probably dies out. The Miocene of western Louisiana is the third most productive trend producing mostly gas, and the Pleistocene of western Louisiana ranks fourth.

The prospective horizons of the upper slope of offshore Texas should consist of a veneer of Miocene and Pliocene with thicker intervals of Pleistocene. The Pleistocene sediments are considered the most prospective reservoir beds and the thickness of these deposits on the slope is variable but at least 10,000 feet of sediments, predominantly clay, is estimated to be present in several synclines on the continental slope.

(c) Geologic Hazards

The major potential geologic hazard on the north-central Gulf OCS concerns the instability of recent bottom sediments in the area of the Mississippi River delta. Recent studies of mud slide hazards in this region were conducted by the U.S. Geological Survey with the cooperation of the Coastal Studies Institute of Louisiana State University. Figure 36 representing

Figure 36.



Note: These designations indicate in a relative way the **likelihood** of encountering locations unsuitable for construction. However, even in zone of least stability, stable locations exist.

PRELIMINARY MAP SHOWING ZONES OF RELATIVE BOTTOM SEDIMENT STABILITY preliminary results of that study, delineates areas within which adverse foundation conditions may exist.

The problem of foundation failure is not a new one to most operators in deltas areas around the world,some of whom have experienced a variety of mishaps ranging from pipeline ruptures to the total loss of costly production platforms. Intensive investigations of a number of such mishaps have been conducted by the major oil companies and the Government. Some of the pioneering work in this field by Shell Oil Company (e.g., Sterling and Strohbeck, 1973; Bea and Arnold, 1973) suggests that in some cases fluctuating pressures within the upper 100 feet of sediment caused by storm waves may trigger a sediment failure. Other investigations conducted at Louisiana State University indicate the content of dissolved and undissolved gases in sediments may play an important role in their instability. Most students of the subject agree that for certain deltaic types, such as the modern Mississippi delta, the principal process which moves sediment seaward from river mouth to the shelf edge is a sort of plastic flow. The mechanism governing this process and the rates at which it occurs are just beginning to be investigated, and its role in local instabilities is yet to be evaluated.

High resolution seismic reflection and side-scan sonar data can reveal surface and subsurface detail to a sub-bottom depth of about 2,000 feet. Potential surface and shallow geologic hazards such as mud waves, slumps, and shallow faults can be identified prior to drilling or rig placement.

Recent engineering investigations concerning platform design and rig placement in areas with unstable bottom sediments suggest that potential damage to these structures can be minimized by increasing both the strength of support members and the depth of sub-bottom penetration of these members; pilings would be driven into more competant strata below the zone of instability.

Seismic risk along the Louisiana coastal region has been classified as Zone 1 (expected minor damage); coastal Texas as Zone 0 (no expected damage) (Algermissen, 1969). Delineation of seismic risk in offshore areas is more tenuous. Areas offshore Texas are thought to have low seismic risk, however the higher possibility of massive sub-sea slumping of deltaic sediments offshore eastern Louisiana gives this OCS area a slightly higher seismic risk value than the adjacent land area.

Additional hazards in the Western Gulf area involve: a) the presence of shallow (<1000') gas deposits offshore Texas and their related blowout potential; b) local relative land subsidence along some coastal areas (Turner, et. al. [1966] reported maximum subsidence of up to five feet in the Houston, Texas area during the last 25 years); and c) shifting sediments along nearshore areas off Texas in response to storm activity.

b. Climate

(1) General Climatology and Seasonal Weather Patterns

The climate of the Gulf of Mexico Region is broadly determined by the huge continental land mass lying to the north and west, the subtropical latitude, the influence of the persistent Atlantic high-pressure system (Bermuda-Azores), and the warm waters of the Gulf itself.

From March through September the eastern Gulf lies under the western portion of the well developed Bermuda high-pressure cell. Around this cell winds move in a clockwise spiral. Due to this influence winds in the Gulf Region are south to southeasterly much of the time with a tropical maritime (Tm) air mass dominating the region almost completely.

In the western Gulf during the summer months, tropical continental (Tc) air masses may occasionally approach from the southwestern U. S. or northern Mexico. On these occasions very high temperatures and low humidity extend eastward toward the coast. During the summer the Bermuda high strengthens westward, and the pressure gradient steepens across Texas toward a semi-permanent thermal low in the region of northwestern Mexico. This produces moderate to strong southeasterly winds almost every day.

By May the semi-permanent Bermuda high becomes well developed. Westerly storm systems are generally too weak to penetrate the strong ridge of high pressure extending westward across the Gulf of Mexico.

Easterly moving systems which influence the Gulf coastal weather seldom occur this early in the year. Occasionally, tropical disturbances and easterly waves will appear in the Gulf of Mexico by early summer.

In summer, the Bermuda high becomes very strong and extends its anticyclonic influence over the Gulf. The prevailing southerly winds from the Gulf provide a rich source of moist tropical air which results in almost daily shower activity along the coast and near-shore waters of the northern Gulf. Air mass thundershower activity increases during the day with the greatest activity in the afternoon. Summer rainfall is generally associated with southerly winds. When westerly to northerly winds occur in summer, periods of hotter and drier weather interrupt the moist semi-tropical climate of this coastal region.

By August, easterly waves and tropical storms increase in the Gulf of Mexico and reach a peak in September. They begin to affect the weather in the Gulf with the principal paths of tropical storms into the Gulf coming from the straits of Florida and the Yucatan Channel. Over half of these tropical storms become hurricanes.

By mid fall the semi-permanent Bermuda high brings its migratory movement eastward in the Atlantic. By November westerly systems bring their influence upon the weather in the Gulf and adjacent coastal regions. Advection (predominantly horizontal, large-scale motions of the atmosphere) and frontal fog make their appearance. The maritime tropical climate along this coastal region affords mild winters, cool springs, warm summers and pleasant autumns.

In winter the area is subjected alternately to maritime tropical and polar continental air (Pc) masses in periods of varying length. This region is usually south of the average track of winter cyclones but occasionally one will move this far south. Westerly systems at times make their influence felt as cold fronts from the northwest push southward into the Gulf of Mexico. The cold air behind these fronts, though modified by the southward journey, brings sudden and occasionally large drops in the temperature. The Gulf of Mexico, with its relatively warm waters, introduces retarding and modifying effects upon cold fronts. As the invading cold air mass pushes out over the Gulf it moves against the strong flow of maritime tropical air in the opposite direction causing the front to become quasi-stationary. At these times the Northern Gulf area becomes a favored region for cyclogenesis (formation of circular wind movement and low pressure). When waves develop on the front they are usually associated with an eastward-moving upper air trough. The principal track of the associated low center parallel the Gulf Coast or moves inland producing persistent low stratus cloud ceilings and rain in the Northern Gulf area. These conditions usually persist ahead of the low centers. The colder air masses in winter tend to gradually lower the sea surface temperature offshore. This plays an important role in the formation of advection-radiation fogs in coastal areas from November-March and the formation of dense sea fog over the relatively cold water surface. The direction of flow of warm air at the surface near the coast determines where the fog will form. Snow seldom occurs this far south in winter. With the arrival of spring, the occurrence of fog, rain and low ceilings becomes less frequent.

During the period October through February, a western anticyclonic cell separates from the Bermuda anticyclone. This cell first appears in October over northeastern Texas with northeasterly winds over the eastern Gulf. During the period November through February, this anticyclonic circulation is nearly stationary over the central Gulf on the mean monthly charts, and the flow over the eastern Gulf is predominantly from northwest and north.

Two remaining air mass types occasionally reach the Gulf, with decreasing frequencies toward the southern coasts. During the late fall and during the spring polar maritime (Pm) air may push into the Gulf where it is rapidly modified. Arctic (A) air mass invasions are normally confined to the months of January and February. Although these air masses are considerably modified by the time they reach the Gulf, sub-freezing temperatures may at times be carried over land to near the extreme southern limits of the area.

(2) Sky Cover and Visibility

Cloudiness. Along the Gulf Coast cloudiness averages between 5 and 6 tenths sky cover with relative small seasonal variation. October is generally the clearest month and December through March the cloudiest. The nature of the cloudiness varies with the season. In winter the Gulf Coast has occasional gray, overcast days but in summer these are rare.

During the warm season, May through September, cumulus clouds begin developing at coastal and near coastal stations several hours after sunrise, reach a maximum of sky coverage between 10:00 a.m. and noon, decrease in intensity during the afternoon, and dissipate near sunset.

Fog. Warm, moist Gulf air blowing slowly over chilled land surfaces brings about the formation of fog at the ground. From November through April, fog is encountered occasionally at points throughout the Gulf coast region. It is most frequent in the vicinity of harbor entrances and over land areas extending into the Gulf, such as Cape San Blas. Fog forms with southerly winds and dissipates during northerly winds.

Fog is relatively infrequent at most Florida coastal points, with the exception of Tampa in the winter. There is a greater frequency along the Alabama and Louisiana coasts and the Texas coastal bend, with lesser amounts on the southwest Texas coast. The heaviest occurrence of fog is usually in the early morning hours. It is generally at a maximum in winter with little heavy fog in summer.

(3) Surface Wind Patterns

The Azores-Bermuda atmospheric high pressure cell dominates the circulation over the Gulf, particularly during the spring and summer months. In late summer there is a general northward shift of the circulation and the Gulf comes under the more direct influence of the equatorial low pressure belt. During the relatively constant summer conditions, the southerly position of the Azores-Bermuda cell brings about prodominance of southeasterly winds. The winds tend to become more southerly in the northern part of the Gulf. During the winter, winds usually blow from easterly directions with fewer southerlies but more northerlies. Winds from west and southwest are rare anytime during the year.

Near the Gulf Coast winds are more variable than over the open waters of the Gulf because the coastal winds fall more directly under the influence of the moving cyclonic storms that are characteristic of the continent.

(4) Air Temperatures

Average temperatures at coastal locations vary with latitude and exposure, and in winter depend, in addition, on the frequency and intensity of penetration by polar air masses from the north. These incursions, when they bring strong northerly winds to the Gulf, are called "northers" and may occur some 15 to 20 times between November and March.

Air temperatures over the open Gulf exhibit narrower limits of variation both on a daily and seasonal basis. In July, average temperature over the center of the Gulf is about 85°F and gradually increases coastward to within 10°F of temperatures recorded at coastal localities. In January, average air temperatures over the Gulf are highest in the southeast, near Cuba and the Yucatan Peninsula, and decrease toward the north. East of Brownsville/Corpus Christi, January air temperatures over the open Gulf average about 65°F; at the Galveston-Mississippi Delta latitude, the temperature is about 60°F.

(5) Precipitation

Average annual precipitation along the Gulf coast increases from approximately 27 inches at Brownsville to over 40 inches at Galveston, 54 inches at New Orleans, and reaches a maximum in the vicinity of Mobile, which receives over 68 inches. Peninsular Florida generally receives over 50 inches of rainfall

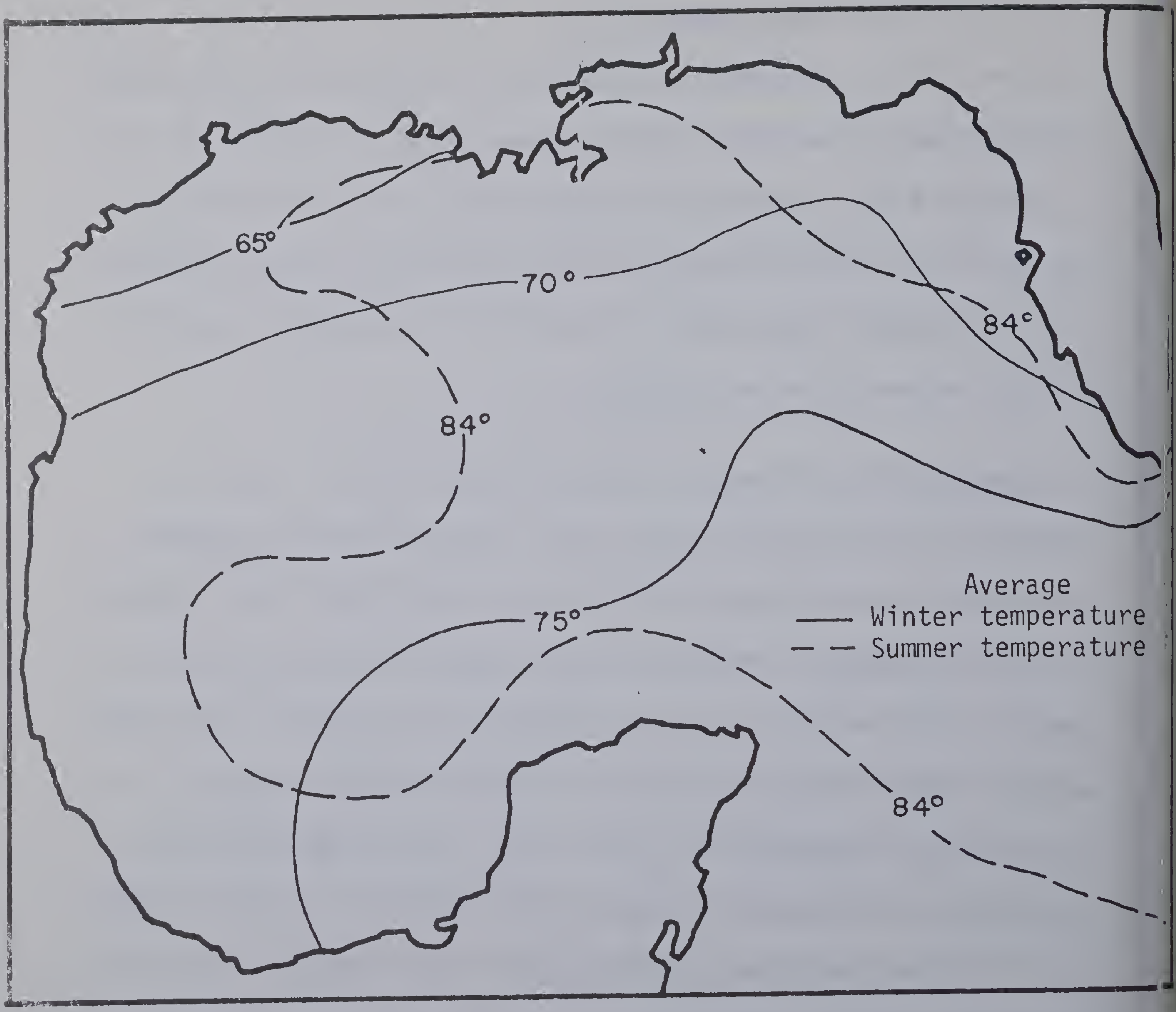


Figure 37. Average summer and winter surface isotherms in °F for the Gulf of Mexico (Leipper, 1954).

3.8

per year; values decline off the tip of Florida where Key West receives 40 inches.

Along the central Gulf precipitation is frequent and abundant throughout the year. At New Orleans, October is the only month with a precipitation average less than 3 inches. July, the wettest month, receives just under 7 inches. Stations along the entire Gulf coast record the highest precipitation values during the warmer months of the year. The month of maximum rainfall for most locations is July, however, at the extreme ends of the Gulf coast, Key West and Brownsville record maximum in September.

These warmer months usually have convective cloud systems which produce showers and thunderstorms; however, thunderstorms of this type rarely cause any damage or have attendant hail. Tornadoes and waterspouts are also extremely rare in this area (Brower, et al., 1972).

Heavy rainfall amounts associated with tropical cyclones account for the high monthly average in September. In Octover, 1937, a record fall of 25 inches was recorded at New Orleans, approximately eight times the normal amount for that month.

Winter rains are associated with the frequent passage of frontal systems through the northern Gulf area. Rainfalls are generally slow, steady, and relatively continuous often lasting several days. Snowfalls are rare, and when frozen precipitation does occur it usually melts upon contact with the ground. A major exception of this occurred in January of 1973, during which time ice, snow and freezing rain fall in large amounts along the Gulf and portions of southeastern U.S. Incidence of frozen precipitation decreases with distance offshore and rapidly reaches zero.

(6) Severe Storms

Tropical Cyclones

The largest and most destructive storms affecting the Gulf of Mexico and adjacent coastal zone are tropical cyclones. Tropical cyclones are low pressure storm systems that have their origin over the warm tropical waters of the central Atlantic Ocean, Caribbean Sea, or southeastern Gulf of Mexico. They, by definition, must have winds in excess of 34 knots, and if the winds exceed 64 knots they are considered hurricanes. Tropical cyclones occur most frequently between June and late October (Brower, 1972) and there is a relatively high probability that tropical cyclones will cause damage in the Gulf of Mexico each year. Statistics for hurricanes and tropical cyclones are often lumped together since it is often difficult, especially in the older records, to determine the storm intensity while at sea. The probability of a tropical cyclone or hurricane influencing the north-central Gulf Coast during any given year is 1 in 6. The earliest and latest occurrence of tropical cyclones for the period 1886-1970 is from the months of May through November.

Most hurricanes and tropical cyclones influencing the Gulf of Mexico form in the eastern Caribbean or the central Atlantic Ocean and there is adequate warning, often as long as several days, of the impending danger. There is no preferred approaching route of hurricane tracks although early season cyclones approach generally from the southeast while later ones are more out of the south. In spite of the fact that most hurricanes form in the tropical ocean areas, a few are generated in the Gulf of Mexico. During the period 1901-1971, seven hurricanes and seven tropical storms formed in the Gulf north of 25°N and east of 85°W.

The data in Table shows occurrences of tropical cyclones and hurricanes for three selected locations along the Louisiana coast.

Table 15 shows Texas storm data by area.

Damage from hurricanes results from high winds and, particularly in the coastal areas, the storm surge or storm tide which is an abnormal high rise in the water level. Maximum surge height at any location is dependent on many factors including bottom topography, coastline configuration, and storm intensity. The storm surge at Pass Christian, Mississippi associated with

Table 15. Occurrence of tropical cyclones and hurricanes for selected Louisiana coastal sites (Data from Brower, 1972).

	Total no. 1899-1971	Avg. No. of Years Between Occurrences
Sabine Pass Area		
Tropical Cyclones	32	2.3
Hurricanes	15	4.9
Bayou Lafourche Area		
Tropical Cyclones	45	1.6
Hurricanes	18	4.1
Southwest Pass Area		
Tropical Cyclones	49	1.5
Hurricanes	18	4.1

hurricane "Camille" in 1969 was 25 feet, and that associated with "Betsy" in 1965 reached nearly 20 feet at Bayou Lafourche (U.S. Army Corps of Engineers, 1970). Hurricane "Camille" was the most severe hurricane in recent Gulf history, with top winds estimated at 201.5 miles per hour, and barometric pressure in her calm eye as low as 26.61 inches of mercury.

Hurricanes may occur at random; however, the incidence of tropical storm occurrences in the western Gulf of Mexico is not as high as the eastern Gulf of Mexico. Three areas of the Texas coast are listed with their storm occurrences and pertinent data in Table 16. Individual storm damage for the three populated areas of the Texas

TABLE 16

TEXAS STORM DATA BY AREA

e	Total No.	Av.No. Years	Mean Recurrence Interval			
torm Type	1899-1971	Of Occurrence	5yr.	10yr.	25yr.	50yr.
rus Christi						
ropical Cyclones	41	1.8				
urricanes	25	2.9				
xtreme Wind			75	85	95	105
ave Height			33	37	42	48
leston-Freeport						
ropical Cyclones	35	2.1				
urricanes	23	3.2				
xtreme Wind			75	85	95	105
ave Height			29	32	37	41
ne Pass						
ropical Cyclones	32	2.3				
urricanes	15	4.9				
xtreme Wind			80	90	100	101
ave Height			30	33	38	42

eme Wind = Maximum Sustained Wind in Knots

Height = Maximum Height in Feet

coast is shown greater than 50 million dollars and up to 500 million dollars.

Hurricanes vary considerably in intensity, track patterns, and behavior upon crossing land, but several processes and their effects are common to all hurricanes. McGowen, et al., (1970), in describing these processes, explains that the storm approach is marked by rising tides and increased wind velocities; generally the longer a storm lingers in the Gulf, the larger the bulge of water it pushes ashore as it approaches land. These storm tides are commonly higher in the bays than on Gulf sea beaches, although flooding and pounding waves affect both areas. Hurricane Carla, in 1961, produced 22-foot tides in Lavaca Bay, Texas; Hurricane Camille, in 1969, produced 22.6-foot tides at Pass Christian, Mississippi.

The flood tides and high waves carry shells and sediment from deeper offshore areas onto seaward beaches, spreading a veneer of deposits over the broad, flat hurricane beaches. In the marsh areas extensive and prolonged inundation and ponding occurs, resulting in damage or loss to habitat and man-made structures. The storm surge flood may also produce breaches or channels in natural barrier islands or in levees.

As the storm passes over the shore, the pattern of current and wave attack shifts into compliance with the direct influence of the counterclockwise winds of the hurricane. Water and sediment are pumped out of bays and flooded areas into the Gulf through passes and breaches on the left side while still being pushed shoreward or as the storm comes ashore, and in the vicinity of the eye, rapid changes in atmospheric pressure and the change in wind direction as the eye passes produce great stresses on structures.

Extratropical Cyclones

In addition to the tropical cyclones, extratropical cyclones that may vary greatly in intensity occur in this area primarily during the winter months. These storms have attained wind speeds as great as 30 to 50 knots. They originate in middle and high latitudes forming on the fronts that separate different air masses. The Gulf of Mexico is an area of cyclone development during the cooler months due to the contrast in temperatures of the warm air over Gulf waters and the cold continental air over the United States. These storms rapidly dissipate, or move on, after moving out over the Gulf of Mexico.

c. Physical Oceanography

(1) Sea Surface Temperatures

Leipper (1954) presents figures for average February and August sea surface temperatures for the Gulf of Mexico; they are reproduced on the following pages as Figs. 38 and 39. According to Leipper the main feature of the average winter pattern is a gradual drop from approximately 75°F in the south to 65°F in the north in all parts of the Gulf. In the summertime, average temperatures are very nearly uniform at 84°F throughout the Gulf. Years of investigations have shown that considerable deviation from these average isotherms may occur at certain times.

(2) Salinity

The salinity patterns of the Gulf of Mexico are principally determined by: (1) inflow of ocean waters through the Yucatan Strait, (2) precipitation and inflow of fresh water from land sources, (3) evaporation, (4) circulation and mixing, and, (5) outflow through the Straits of Florida. In the northern Gulf, runoff from the Mississippi and Atchafalaya and from smaller rivers to the east and west gives rise to a band of low-salinity water (Nowlin, 1972). Typical salinities are seen in Figure 40.

(3) Surface Circulation

Water movements in the Gulf of Mexico are controlled by a variety of interacting forces including fresh water inflow from land, currents set up by winds, currents and water transport induced by surface gravity waves, tidal currents, currents associated with internal waves, and movement of water masses due to density differences.

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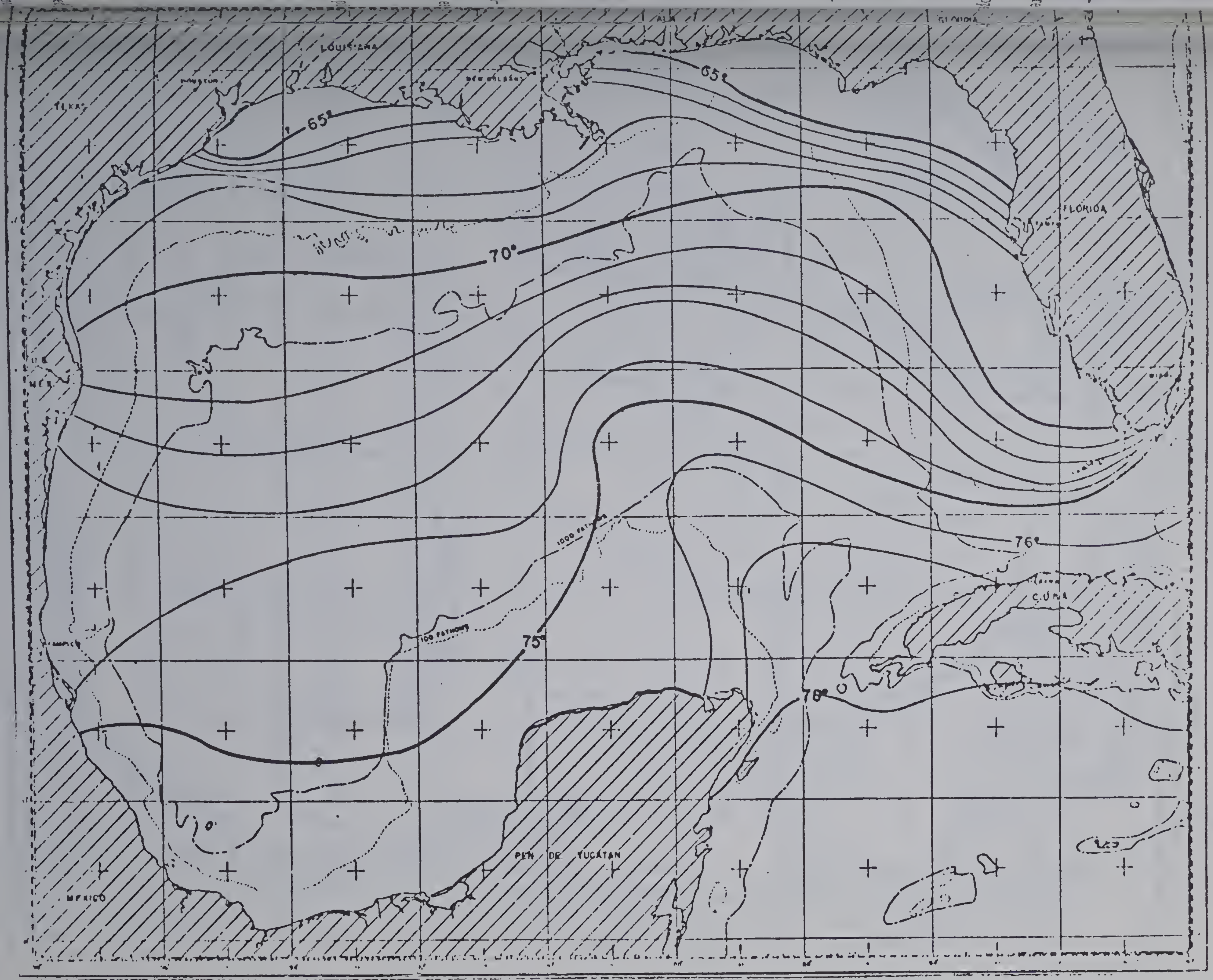

Figure 38. Average sea surface temperatures for February (after Fuglister, 1947). (From Leipper, 1954)

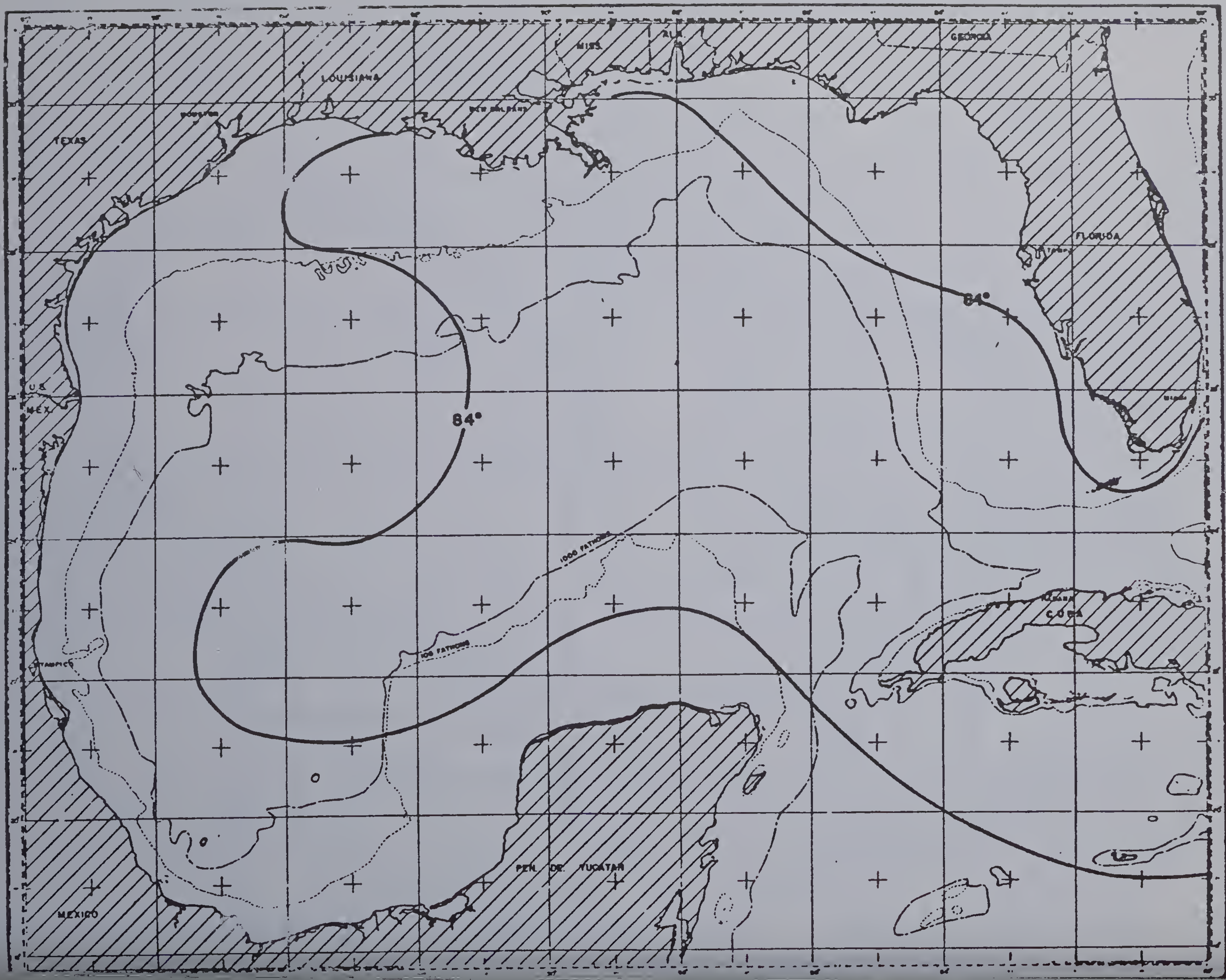

Figure 39. Average surface sea temperatures for August (after Fuglister).

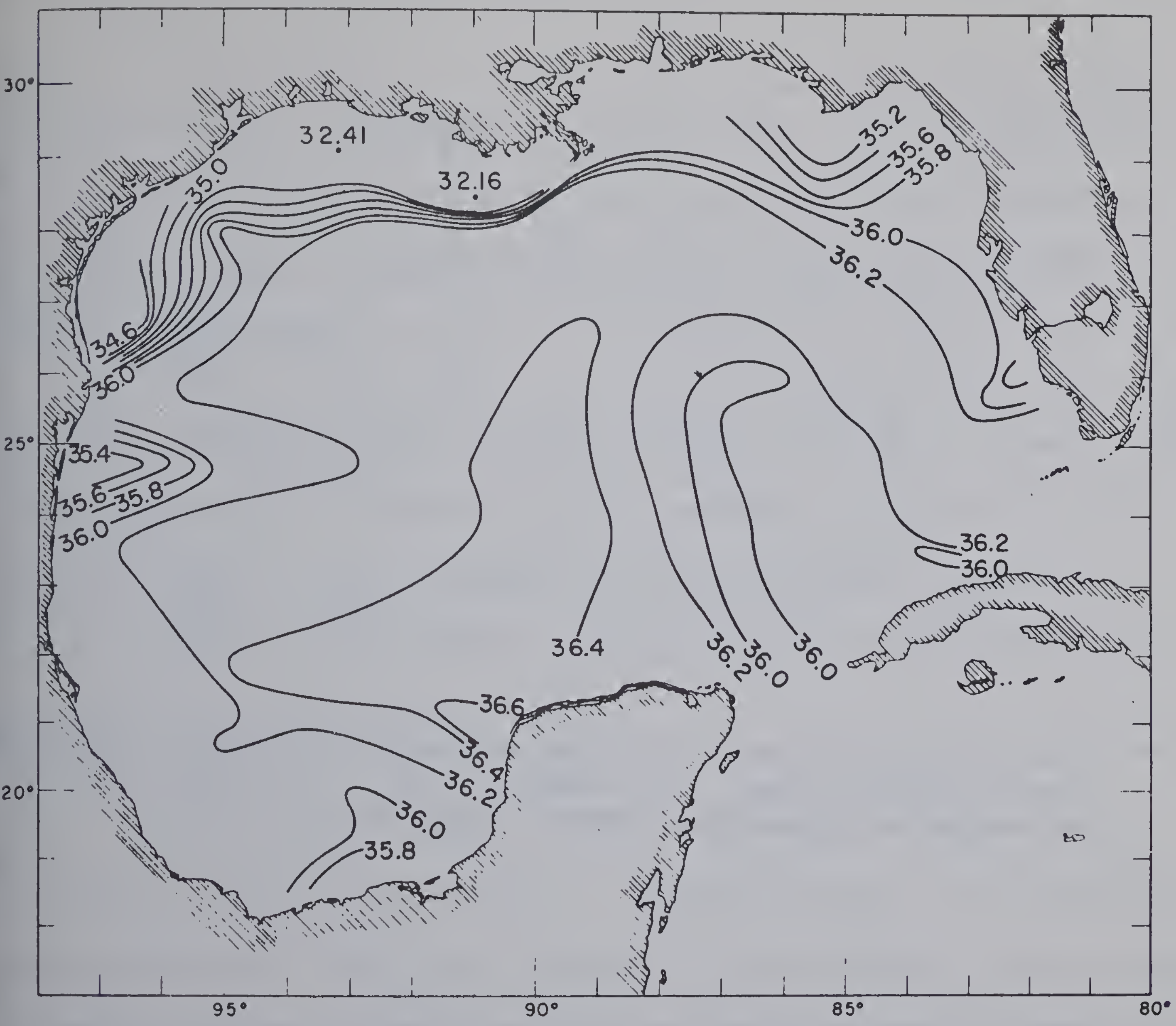

Figure 40 . Typical surface salinities (parts per thousand) in the Gulf of Mexico (from Nowlin, 1972).

wlin

The general circulation pattern for the eastern Gulf consists of a clockwise Loop Current flowing in through the Yucatan Strait and out through the Florida Strait (Fig.41). This is essentially an extension of the Yucatan Current which flows into the Gulf, circles to the right and flows out through the Florida Strait to join the Gulf Stream Current. A counterclockwise gyre off the west coast of Florida is a persistent feature, more defined during the winter months, however. The western half of the Gulf has no strong, semi-permanent currents but is characterized by a

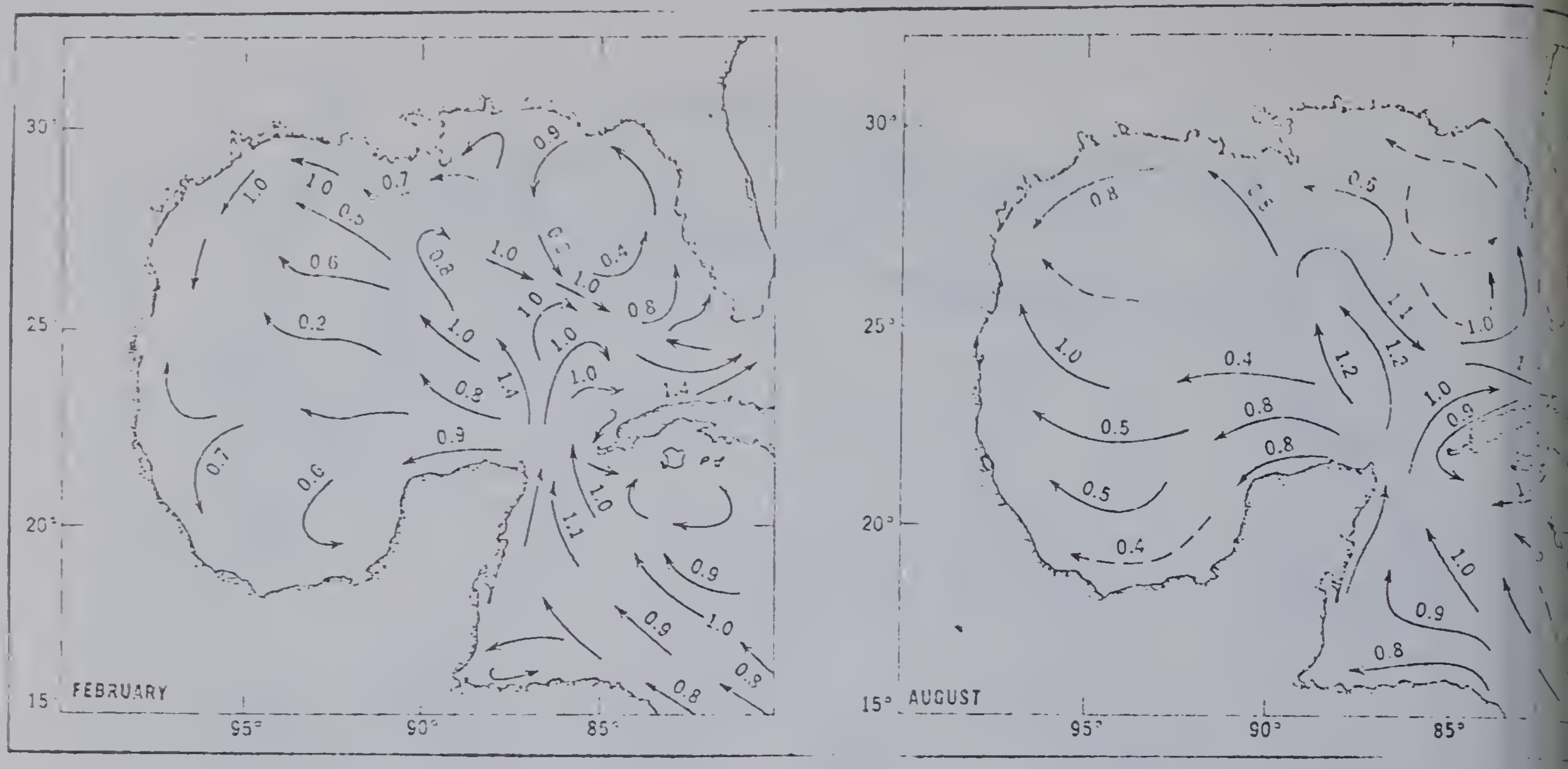

Figure 41. Generalized surface circulation in the Gulf of Mexico inferred from logs of ships at sea. The numbers refer to current speeds in knots, as estimated from ships' drift. (From Nowlin, 1971)

well-defined pattern of winter flow and a highly variable summer pattern (Nowlin, 1971). There is a general westward sweep of currents along the northern shelf west of the Mississippi Delta. Anothe mass of water moves northward along the Mexican coast to a zone of convergence off Texas. All the currents in the western Gulf seem to flow toward this general zone.

The eastern Gulf shelf from the Mississippi Delta to Cape San Blas is characterized by a very mixed current pattern reflecting influences o variable winds and fresh water inflow upon water mass movements resulting from the Loop circulation. Eastward from Cape San Blas, the current directions reflect a semi-permanent counterclockwise gyre which flows northward along the west coast of Florida, swings westward south of

Apalachee Bay, and turns south off Cape San Blas. There are places and times where this gyre is weak or non-existent. Thus, some bays and inlets, as well as some open beaches, are isolated from tidal and current exchanges.

Figure 42 depicts surface circulation trends along the Louisiana coast, emphasizing the general westward movement of currents. The nearshore regime in this area is influenced by several factors, among them winds, tides, offshore current flow, and fresh water discharge from coastal rivers.

Currents around the Mississippi Delta are strongly influenced by the fresh water outflow from the river. At Head of Passes, the Mississippi River branches into three major channels: Pass-a-Loutre, transporting 37% of total river discharge; South Pass, 29%, and Southwest Pass, 15%. Fresh water discharge rates vary seasonally with highest values occurring during the spring, lowest in the fall. Outflow from the Mississippi Delta maintains its general integrity as it passes over the more dense, saline underlayer. Scruton (1956) observed a fresh water plume extending 20 miles off Pass-a-Loutre. This has been confirmed in unpublished work by Charles Eleuterius, Gulf Coast Research Laboratory, whose data indicates that at times this plume extends some forty miles

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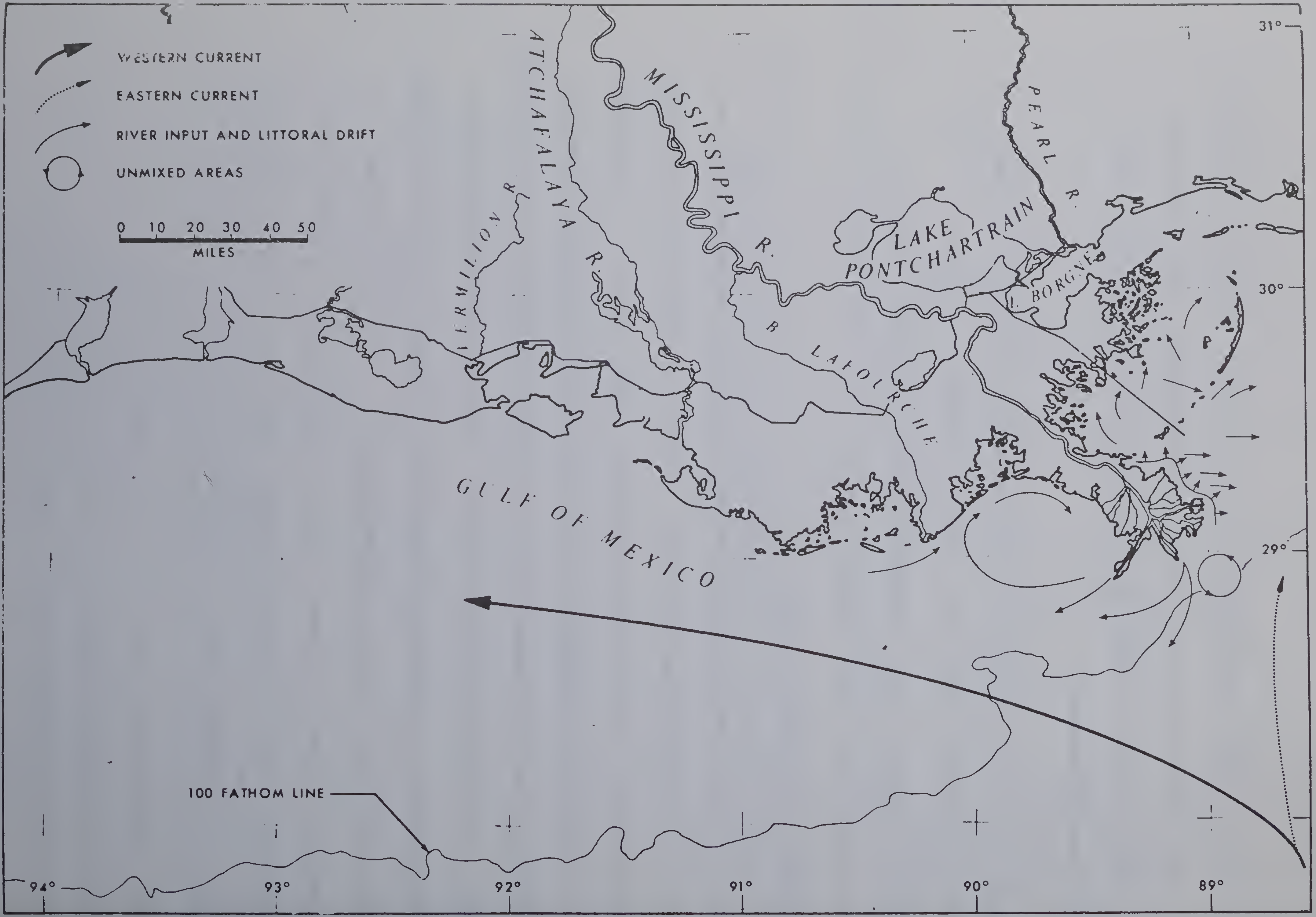


Figure [illegible]. Generalized surface [illegible]
(From Stone, 1972).

eastward. Fresh water plumes to the south and west are less well known; however, they undoubtedly exert considerable influence.

After sweeping westward along the Louisiana continental shelf, prevailing surface currents turn southwestward, roughly paralleling the Texas Coast (Fig. 43). Another surface current system moves northward along the Mexican Coast to a zone of convergence off Texas. The actual area in which the north and south moving currents converge changes throughout the year in response to atmospheric conditions. In winter (Figure 43) the area is to the south of the U. S. - Mexican border. The area shifts gradually northward during the spring and summer months (Figure 44). Current velocities range in speed from about 0.4 knots to 1.5 knots.

(4) Tides

The tides of the Gulf of Mexico are weakly developed and usually their observed range does not exceed 0.7 meters (Durham and Reid, 1967). Semidiurnal (twice daily) tides are small, and therefore, the tide in the Gulf is considered diurnal (daily) in character. In 1897, R. A. Harris (in Grace, 1932) suggested that the diurnal tides of the Atlantic Ocean influenced the tides in the Gulf through the Yucatan Channel. Later in 1900, he expressed the opinion that a single oscillating system with a nodal line extending from Western Haiti to Nicaragua is formed by the Gulf of Mexico and the Caribbean Sea. This would cause the tides of the Gulf to be simultaneous. In 1908, Endros (in Grace 1932) arrived at a similar conclusion considering the Gulf and the Caribbean Sea to be a single oscillating body with a period of nearly 24 hours.

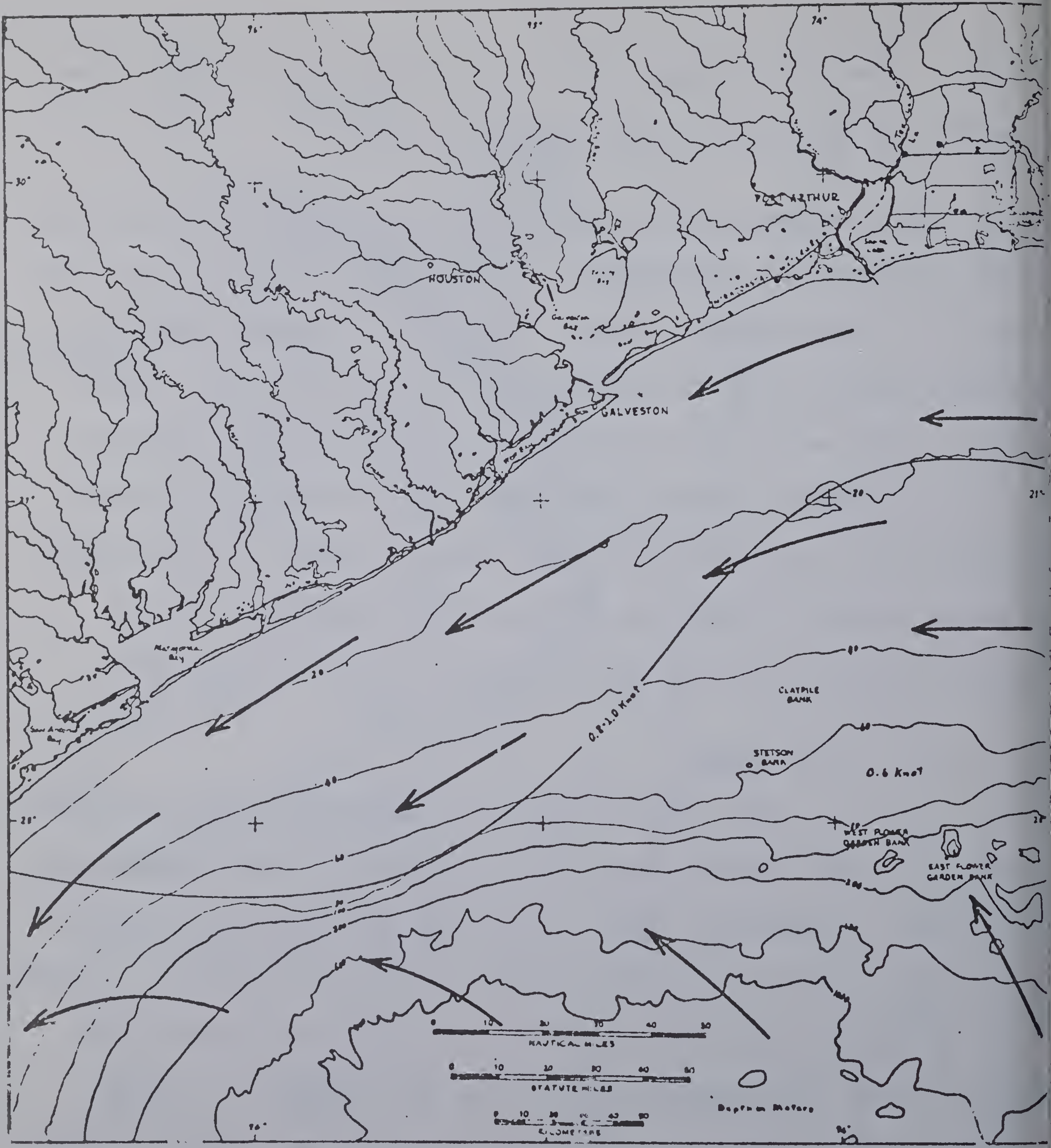


Figure 43 . Surface currents in January
(U. S. Dept. of Army, 1973).

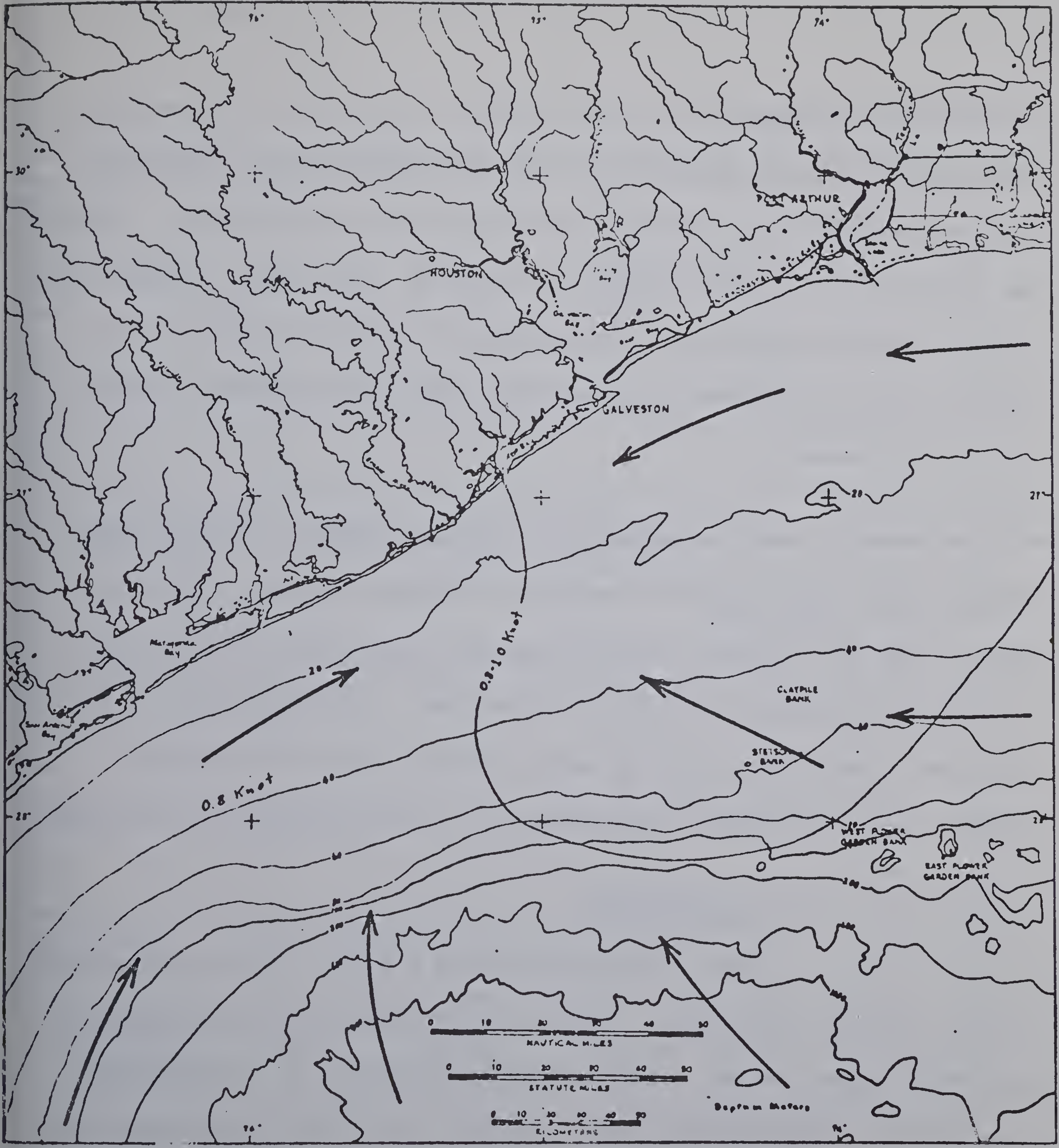


Figure 44. Surface currents in July (U. S. Dept. of Army, 1973).

Also in 1908, G. Wegmann (in Defant, 1961), considered the resonance effect of the diurnal components of the Gulf and found the period of free oscillation for an east-west oscillation to be 24.8 hours. According to work by S. F. Grace (1932), the diurnal tide enters through the Florida Straits, progresses counterclockwise around the basin, is reflected by the northwestern and southern coasts and egresses through the Yucatan Channel.

When the moon is near its maximum declination (angular distance from equator), the tide is diurnal and has the greatest range. When the moon is over the equator, the tide has the least range and there may be several days having two highs and two lows. Although tides in the Gulf have a small range they do have important roles in modifying currents and accelerating the movement of water through narrow passages.

(5) Sea and Swell

When wind speeds exceed 2 knots, waves are generated in the vicinity of the wind. Winds of increasing velocity create progressively higher waves. Swell is the term applied to the generally long period waves which have been generated by winds in areas some distance from the area of reference.

Wind speeds prevalent in the Gulf are responsible for waves which have a mean height of 3 to 4 feet (Table 17).

Higher wave heights occur during the period November, December, January, February, and March when stronger winds blow out of the north. Prevailing

Table 17.
Wave Heights, Gulf of Mexico (from Breuer et al, 1972).

AREA: Panama City — CENTRAL POSITION: 30° 00'N 86° 00'W

ENVIRONMENTAL FACTORS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
WAVES (FEET)													
01% ≤	1	1	1	1	1	1	1	1	1	1	1	1	1
05% ≤	1	1	1	1	1	1	1	1	1	1	1	1	1
25% ≤	2	2	2	2	1	1	1	1	2	2	2	2	1
50% ≤	4	4	4	3	2	2	2	2	3	4	4	4	3
75% ≤	6	6	6	4	4	4	3	3	5	6	6	6	5
95% ≤	10	10	8	7	5	5	5	5	10	8	8	8	8
99% ≤	12	16	12	10	10	7	7	7	15	13	10	13	12
Maximum observed	15	23	15	13	13	12	12	13	16	15	16	18	23
Mean	4	4	4	3	2	2	2	2	3	4	4	4	3
≥ 5 Feet (% freq.)	43.6	39.5	33.6	23.3	15.5	11.2	7.3	9.9	27.2	36.6	35.4	36.5	26.6
≥ 8 Feet (% freq.)	10.9	11.2	6.3	2.9	3.1	4.0	0.4	0.7	8.1	7.8	5.0	7.6	5.3
≥ 12 Feet (% freq.)	3.5	3.0	1.8	0.7	0.5	0.2	0.2	0.2	3.0	1.5	0.6	2.1	1.4
≥ 20 Feet (% freq.)	0.0	+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	+

AREA: Mobile - Pascagoula — CENTRAL POSITION: 29° 40'N 88° 30'W

ENVIRONMENTAL FACTORS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
WAVES (FEET)													
01% ≤	1	1	1	1	1	1	1	1	1	1	1	1	1
05% ≤	1	1	1	1	1	1	1	1	1	1	1	1	1
25% ≤	1	2	1	1	1	1	1	1	1	1	1	1	1
50% ≤	3	3	3	2	2	1	2	2	3	3	3	3	2
75% ≤	5	5	4	4	3	3	3	3	4	5	5	4	4
95% ≤	8	7	7	7	5	5	5	5	8	8	7	7	7
99% ≤	13	12	12	10	7	8	7	7	13	10	12	10	10
Maximum observed	16	31	15	15	10	10	10	12	15	20	15	13	31
Mean	3	3	3	3	2	2	2	2	3	3	3	3	3
≥ 5 Feet (% freq.)	26.4	28.6	22.0	18.0	9.5	6.5	7.8	9.2	25.0	28.3	27.4	24.0	19.5
≥ 8 Feet (% freq.)	5.3	5.1	5.5	2.7	0.7	1.0	0.4	0.9	5.9	6.1	4.4	4.0	3.6
≥ 12 Feet (% freq.)	1.3	1.4	1.1	0.5	+	+	+	0.1	1.6	0.7	1.4	0.4	0.8
≥ 20 Feet (% freq.)	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	+

AREA: Southwest Pass — CENTRAL POSITION: 28° 56'N 89° 29'W

ENVIRONMENTAL FACTORS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
WAVES (FEET)													
01% ≤	1	1	1	1	1	1	1	1	1	1	1	1	1
05% ≤	1	1	1	1	1	1	1	1	1	1	1	1	1
25% ≤	2	2	2	2	1	1	1	1	1	2	2	2	1
50% ≤	4	4	4	3	2	2	2	2	3	3	4	4	3
75% ≤	6	6	6	5	4	4	3	3	5	6	5	6	5
95% ≤	9	9	9	7	6	6	6	6	8	8	8	9	8
99% ≤	13	15	13	10	8	8	8	13	13	12	12	12	10
Maximum observed	23	31	21	15	13	21	12	21	31	20	20	21	31
Mean	4	4	4	3	3	2	2	2	3	4	4	4	3
≥ 5 Feet (% freq.)	39.5	39.7	35.3	29.6	17.4	11.9	8.4	11.6	25.6	32.7	36.8	37.2	27.4
≥ 8 Feet (% freq.)	10.1	9.6	8.8	4.5	2.3	1.6	0.9	1.5	7.2	7.3	7.5	8.6	5.8
≥ 12 Feet (% freq.)	2.4	2.9	1.8	0.6	0.4	0.5	0.1	0.5	2.4	1.2	1.7	1.8	1.3
≥ 20 Feet (% freq.)	0.2	0.3	0.2	0.0	0.0	0.1	0.0	0.1	0.2	+	0.1	+	0.1

Table 17, (Continued)

AREA: Sabine Pass

CENTRAL POSITION: 28° 35'N 93° 51'W

ENVIRONMENTAL FACTORS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
WAVES (FEET)													
01% ≤	1	1	1	1	1	1	1	1	1	1	1	1	1
05% ≤	1	1	1	1	1	1	1	1	1	1	1	1	1
25% ≤	2	2	2	2	1	1	1	1	1	1	2	2	1
50% ≤	4	4	4	3	3	2	2	2	3	3	4	4	3
75% ≤	6	6	5	5	4	4	3	4	5	5	6	6	5
95% ≤	9	9	8	7	7	6	6	6	7	7	9	9	7
99% ≤	13	12	12	10	10	8	8	7	12	10	12	12	10
Maximum observed	25	21	25	21	15	28	13	16	23	21	26	20	28
Mean	4	4	4	3	3	3	2	2	3	3	4	4	3
≥ 5 Feet (% freq.)	36.2	36.3	34.4	31.5	24.0	17.1	15.1	12.4	26.1	28.6	37.1	36.3	27.7
≥ 8 Feet (% freq.)	7.7	8.6	6.4	4.0	3.3	2.3	1.2	1.0	4.6	4.7	8.4	7.8	5.1
≥ 12 Feet (% freq.)	1.9	2.3	1.3	0.6	0.5	0.4	0.3	0.2	1.2	0.8	1.5	1.8	1.2
≥ 20 Feet (% freq.)	0.1	+	+	0.1	0.0	+	0.0	0.0	0.1	0.2	0.2	+	+

AREA: Galveston - Freeport

CENTRAL POSITION: 28° 30'N 95° 01'W

ENVIRONMENTAL FACTORS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
WAVES (FEET)													
01% ≤	1	1	1	1	1	1	1	1	1	1	1	1	1
05% ≤	1	1	1	1	1	1	1	1	1	1	1	1	1
25% ≤	2	2	2	2	1	1	1	1	1	1	2	2	1
50% ≤	4	4	3	3	3	2	2	2	3	3	4	4	3
75% ≤	6	6	5	5	5	4	3	3	5	5	5	6	5
95% ≤	9	9	8	7	7	7	6	6	7	7	9	9	8
99% ≤	12	12	12	12	10	10	5	7	10	12	12	12	10
Maximum observed	25	21	25	21	15	28	13	16	20	21	23	25	28
Mean	4	4	4	3	3	3	2	2	3	3	4	4	3
≥ 5 Feet (% freq.)	37.1	35.2	32.7	32.1	25.6	18.7	11.8	12.7	26.5	29.0	37.4	35.8	28.0
≥ 8 Feet (% freq.)	8.0	9.3	7.0	4.8	4.0	3.0	1.1	0.8	4.6	5.0	8.8	8.2	5.5
≥ 12 Feet (% freq.)	1.9	2.7	1.7	1.1	0.7	0.7	0.2	0.2	0.9	1.2	1.9	2.2	1.4
≥ 20 Feet (% freq.)	0.1	0.1	0.2	0.2	0.0	0.2	0.0	0.0	+	0.4	0.2	+	0.[illegible]

AREA: Corpus Christi

CENTRAL POSITION: 27° 45'N 96° 40'W

ENVIRONMENTAL FACTORS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
WAVES (FEET)													
01% ≤	1	1	1	1	1	1	1	1	1	1	1	1	1
05% ≤	1	1	1	1	1	1	1	1	1	1	1	1	1
25% ≤	3	3	2	2	2	2	1	1	1	2	2	3	2
50% ≤	4	4	4	4	4	3	3	2	3	4	4	4	4
75% ≤	6	6	6	6	5	5	4	4	5	6	6	6	6
95% ≤	11	10	9	8	7	7	6	6	7	8	10	10	9
99% ≤	15	13	12	12	10	10	8	8	12	13	15	13	12
Maximum observed	25	21	23	21	21	20	21	23	26	21	24	25	26
Mean	5	4	4	4	4	3	3	3	3	4	4	4	4
≥ 5 Feet (% freq.)	47.8	46.8	38.3	37.6	32.6	26.3	16.4	15.7	27.4	34.5	44.4	43.1	34.3
≥ 8 Feet (% freq.)	14.8	10.9	9.8	6.5	4.7	3.6	2.0	1.1	4.3	7.6	13.0	14.3	7.8
≥ 12 Feet (% freq.)	4.4	2.7	1.6	1.4	0.7	0.9	0.4	0.3	1.2	1.5	3.5	3.8	1.8
≥ 20 Feet (% freq.)	0.5	0.1	0.1	0.2	+	0.2	+	+	0.4	0.3	0.4	0.4	0.2

winds during spring, summer, and early fall are from the southeast and wave heights are generally lower during this period. Waves associated with storms range considerably higher. During hurricane Camille (1969) for example, waves 70 feet high were reported offshore.

d. The Biological Environment

For the purpose of discussion of the biology of the offshore environment, the land margin of the continental shelf is functionally defined as the seaward edge of submerged seagrass bed. Where these beds are absent; it is assumed that the shelf begins at the line of total immersion or mean low water.

The offshore environment is broadly divided into the pelagic and benthic realms. The pelagic realm includes all ocean water above the bottom; over the continental shelf, the waters constitute the neritic province (as opposed to the ocean province above the slope and deep ocean bottom). The biota of the pelagic division is generally subdivided into plankton (organisms that float or drift in the water) and nekton (organisms that are active swimmers). The benthic division includes the sea bottom and sub-bottom environment and its biota is called benthos.

(1) Phytoplankton

All motile aquatic organisms, plant or animal, whose powers of locomotion are too feeble to resist the set and drift of currents are termed plankton (Hardy, 1954). The plankton is divided into several different types on the basis of physiology and life history.

Phytoplankton includes the acellular (unicellular) floating plants and all floating cellular plants such as Sargassum. As plants, all phytoplankters are capable of producing their own food from raw materials by photosynthesis. The ubiquitour distribution and occurrence in pelagic waters is influenced by several factors. Steidinger (1973) stated that both horizontal and vertical distributions of phytoplankton are dependent on: 1) population origin and life cycles, 2) supply and level of nutrients and growth factors, 3) physiological requirements and adaptability, 4) salinity and temperature, and 5) grazing pressure by herbivores (plant-eating animals). In addition, vertical distribution alone is influenced by: 1) vertical water mixing, diffusion, and water stability, and 2) depth of the lighted zone (euphotic zone).

El Sayed (1972) used measurements of chlorophyll a (a bluish black pigment found in phytoplankton) to calculate estimates of the phytoplankton standing crop (total number or weight of living organisms momentarily present in an environmental unit [Pennak, 1964]) for the Gulf of Mexico. Surface chlorophyll a showed higher concentrations (high standing crop) during the winter than at any other season; these were followed by a decrease in the standing crop of phytoplankton during spring, and a gradual increase in summer and fall. In terms of chlorophyll a (sea-surface values and data integrated for the euphotic zone), the Gulf of Mexico is no different from other tropical or subtropical bodies.

The levels of primary productivity (total quantity of green plant protoplasm [living material within the cell] produced per unit time in a specific habitat) (gross primary production) in different geographic localities in the Gulf of Mexico resemble the distribution of the phytoplankton standing crop. As with chlorophyll *a*, the surface and integrated (within the euphotic zone) primary productivity values in the inshore water were higher than those values for offshore waters. The average primary productivity of the Gulf was 0.15 g C/m2/day (El Sayed, 1972).

Several authors have discussed the phytoplankton assemblages of the Gulf of Mexico. Curl (1959) documented the phytoplankton found in Alligator Harbor, Florida and the northeastern Gulf. He noted that the diatoms were most abundant in numbers and species, and the genera *Rhizosolenia* and *Chaetoceros* were responsible for most of the phytoplankton biomass in 1954. The characteristic dinoflagellate was *Podolampas elegans* Schutt.

Simmons and Thomas (1962) described two assemblages associated with different salinity regimes near the Mississippi delta. A low salinity regime of river water has an assemblage dominated by two species each of the genera *Cyclotella*, *Melosira*, and *Navicula*. A higher salinity regime of Gulf waters had an assemblage composed of *Nitzschia seriata*, *Thalassiothrix frauenfeldii*, *Thalassionema nitzschioides*, *Skeletonema costatum*, *Asterionella japonica* and three species of Chaetoceros. This Gulf water regime near the fresh water plume has higher diversity due to mixing of fresh water and marine genera. Seasonality of species (presence and abundance) was more variable in the Gulf regime than in the river regime. In both areas, the lowest abundances (standing crop) were noted in November.

Stowe (1972) studied the diatoms near Barataria Bay, Louisiana, finding Cocconeis, Amphora, and Denticula to be the most abundant genera. Ephiphytic (growing attached to another plant) diatoms showed a continual rise in abundance from January to September, with a generalized bloom occurring from October to November.

Sanders and Fryxell (1972) plotted the distributions in the Gulf of 14 diatom species. The 14 species were selected on the basis of: 1) frequency of occurrence, 2) ease of identification, 3) sufficient size to be retained in net collections, and 4) interesting relationships to environmental influences. Rhizosolenia alata was the most frequently observed species over the entire Gulf, and is found during 11 months of the year. Guinardia flaccida is also found in all months, and the remaining species can be found in most months.

Dinoflagellate distribution was reviewed by Steidinger (1972), who mapped occurrences of 14 frequently found species in the Gulf. Species diversity of dinoflagellates was found to be higher offshore (where it occasionally exceeds diatom diversity) than nearshore, while dinoflagellate abundance was higher nearshore than offshore.

Steidinger (1973) later surveyed the phytoplankton of the eastern Gulf and outlined four broad types of assemblages: 1) estuarine, 2) estuarine and coastal, 3) coastal and open Gulf, and 4) open Gulf.

The open Gulf phytoplankton assemblage would include the diatom genera *Gossleriella*, *Ethmodiscus*, and *Planktoniella*, and the dinoflagellate genera *Triposolenia*, *Heterodinium*, *Amphisolenia*, *Murrayella*, *Histioneis*, *Ptychodiscus*, *Cladopyxis*, and *Kofoidinium*. The dinoflagellates are more diverse in the open Gulf assemblage but they do not necessarily dominate the standing crop. The diatoms are more diverse in the coastal/open Gulf assemblage.

The assemblages described by Steidinger are not meant to imply strict groupings. Many species are found in more than one area, being subject to current and wind patterns. *Rhizosolenia alata* has been found in all four areas. The four groupings show certain associations such as the greater dinoflagellate diversity in open Gulf waters.

(2) Zooplankton

The animal plankters are called zooplankton. Zooplankton distributions and occurrences are also relatively continuous in pelagic waters. In general, they are influenced by the same factors that affect phytoplankton distribution and occurrence. Inorganic nutrients and depth of the lighted zone are not as immediately important to zooplankton as to phytoplankton, but these factors affect distribution and abundance in that greater availability of nutrients and light allow higher primary productivity and consequently a greater food supply for zooplankton.

Data on zooplankton for the Gulf of Mexico shelf waters are limited. Most of the zooplankton studies were restricted to certain groups of organisms and included only the inshore waters. Khromov (1965) indicated a zone of low zooplankton density east of Galveston; southwest of Galveston the nearshore density exceeded 0.5 g/m^3 in the shallow coastal waters with lower densities seaward.

The most important grazers (herbivores) are the copepod crustaceans, which are the most abundant zooplanktonic group in any given plankton sample (Raymont, 1963). The distribution of copepods is dependent on factors mentioned previously for phytoplankters. The herbivores' feeding habit superimposes a localized abundance (patchiness) on the general distribution pattern. Where phytoplankton populations become abundant, copepod populations will also flourish.

Euphausiid crustaceans are also prominent members of the zooplankton assemblage. Feeding habits of euphausiids have variously been described as herbivorous, carnivorous (meat-eating) and detritivorous (organic or inorganic particulate matter eaters). While some, e.g., Euphausia superba in the Antarctic, appear to be strictly herbivorous, it seems best to conclude that euphausiid species are at different trophic levels, or each species has a range of organic material from which to satisfy nutritional requirements (Raymont, 1963).

Possibly the most significant carnivores in the zooplankton are the chaetognaths, or arrow worms. Copepods dominate their diet but this may be an artifact based on relatively high copepod abundance (Raymont, 1963). They also feed on fish and barnacle larvae.

Other common carnivores in the zooplankton include the ctenophores, medusae of various species, ostracods, cladocerans, mysid and amphipod crustaceans, heteropods, pteropods, salps and pyrosomes. Another significant group of carnivores are the various larval and immature forms, both holoplanktonic (planktonic at all stages of its life cycle) and meroplanktonic (organisms which have planktonic reproductive stages), from several phyla. These include most of the crustaceans mentioned, the tunicates, echinoderms, cephalopods, ectoprocts, sponges, annelid and nemertine worms. Fisheries larvae are important carnivores, and the survival of larval of commercial fish has obvious economic import.

(3) Benthic Biota

Organisms (plant or animal) which, as adults or in sessile (stationary) stages of their life cycles, live on the bottom are called benthos. Odum (1971) stated that the benthos ". . .is characterized by the large numbers of sessile or relatively inactive animals which exhibit marked zonation in the inshore region." The organisms are generally distinct for each of the three neritic zones (supratidal or supralittoral, intertidal or littoral, and subtidal or sublittoral), but specific species may be found in more than one zone. Zonation is characterized more by dominant species than by distinct assemblages of numerous species.

The benthic community is in general affected and defined by the same factors that influence the waters above the bottom. Additional factors to consider for the sea bottom alone are: 1) nature of the substrate, 2) nature of the sediment, and 3) sub-bottom temperatures, salinity, oxygen and pH. The substrate may be hard or soft depending on the amount and nature of sedimentation, and the degree of scouring by horizontal currents. Sediment type is usually described by percentages of carbonates, evaporites, sand, silt, and clay. Sub-bottom temperature, salinity, oxygen, and pH can be much different than overlying waters, especially the oxygen and pH values. The benthic environment becomes more stable at greater depths, i.e., it is less affected by physical forces such as currents, waves and storm surges. Temperature and salinity data tend to fluctuate less and have smaller ranges of values than in shallow water areas closer to the air-sea interface.

The major subdivisions of the biota found in the benthic environment are epiflora, epifauna, infauna, and inflora. Epiflora are plant, cellular or acellular, macroscopic or microscopic, which are attached to or living on the bottom. Inflora are plants found in the interstitial spaces of the bottom substrate. The main benthic floral groups are the seagrasses and the benthic algae. The seagrasses have been discussed previously. The benthic algae predominantly inhabit rocky coastlines and hard bottom. The paucity of such habitats in the Gulf of Mexico area allows the seagrasses to dominate the benthic algae. Representatives of the four major phyla of algae (Cyanophyta, blue-green; Rhodophyta, red; Phaeophyta, brown; Chlorophyta, green) may be found in suitable locations, but in offshore water, red and brown algae predominate (Odum, 1971). In exceptionally clear waters, benthic algae are known to grow in at least 600 feet of water, especially coralline red algae, and apparently green, brown, and non-corralline red algae as well (Odum, 1973). Locally, in depths of 60-300 feet, there may be extensive bottom covers of algal nodules, fist-sized spheroidal aggregations or corralline algae and carbonate debris (Logan, 1969).

Benthic fauna are divided into the epifauna and infauna. Animals which live on the bottom are called epifauna. Many species are permanently attached to the bottom. Many of the epifauna are colonial or consist of groups of individuals incompletely separated from one another. These organisms have developed life-forms which appear more like conventional plants than animals. Other epifauna creep about on the bottom, and some are highly motile. The epifauna representatives in Gulf of Mexico waters include almost all animal phyla. They range from the sessile organisms like sponges and anemones to the slower moving forms such as shrimp and crabs to the highly motile demersal fish. Demersal fish are those which live on or near the bottom and depending on the bottom for their food supply. These include the commercially important flounders inshore, red snapper, croakers, sea catfish, groupers, and various other bottom fish that prefer offshore banks.

The southern flounders (Paralichthys lethostigma) prefer sandy or silty bottoms along the shores of the bays, where they bury themselves with only their eyes showing and wait for food. The Atlantic croaker (Micropogon undulatus) frequents the bays and Gulf beaches feeding on crustaceans, molluscs, and smaller fishes. Snapper and groupers school near topographic irregularities, normally at the bases of banks (or rises), and other irregular bottom conditions. Bottom topography of the Gulf of Mexico is well suited for snapper and grouper habitats, and the area has been fished since the turn of the century.

The most important commercial epifaunal species for the Gulf of Mexico are the brown shrimp (*Penaeus aztecus*) found offshore. Other species of commercially important shrimp found in the Gulf of Mexico are the white shrimp (*Penaeus setiferus* - inshore and offshore species). Of lesser importance are the shallow offshore species of sea bob (*Xiphopenaeus kroyeri*) and the royal red shrimp (*Hymenopenaeus robustus*) which is found in the deep waters from 175 to 300 fathoms.

Non-commercial organisms are also important components of the benthic environment. Conspicuous members of certain phyla such as echinoderms, molluscs, decapod crustaceans, and larger annelid worms are better studied than the smaller organisms such as nematodes and foraminiferans. Many of the conspicuous organisms live at the sediment - water interface.

Benthic communities of offshore areas can be broadly described as shallow shelf communities, deep shelf communities, and slope communities. Within these broad areas, more specific communities can be described for shrimp grounds, sand bottoms, silt and mud bottoms, rocky bottoms, and hard banks.

Figures 45 to 47 are modified Petersen diagrams compiled by Collard and D'Asaro (1973) to illustrate the shallow shelf, deep shelf, and

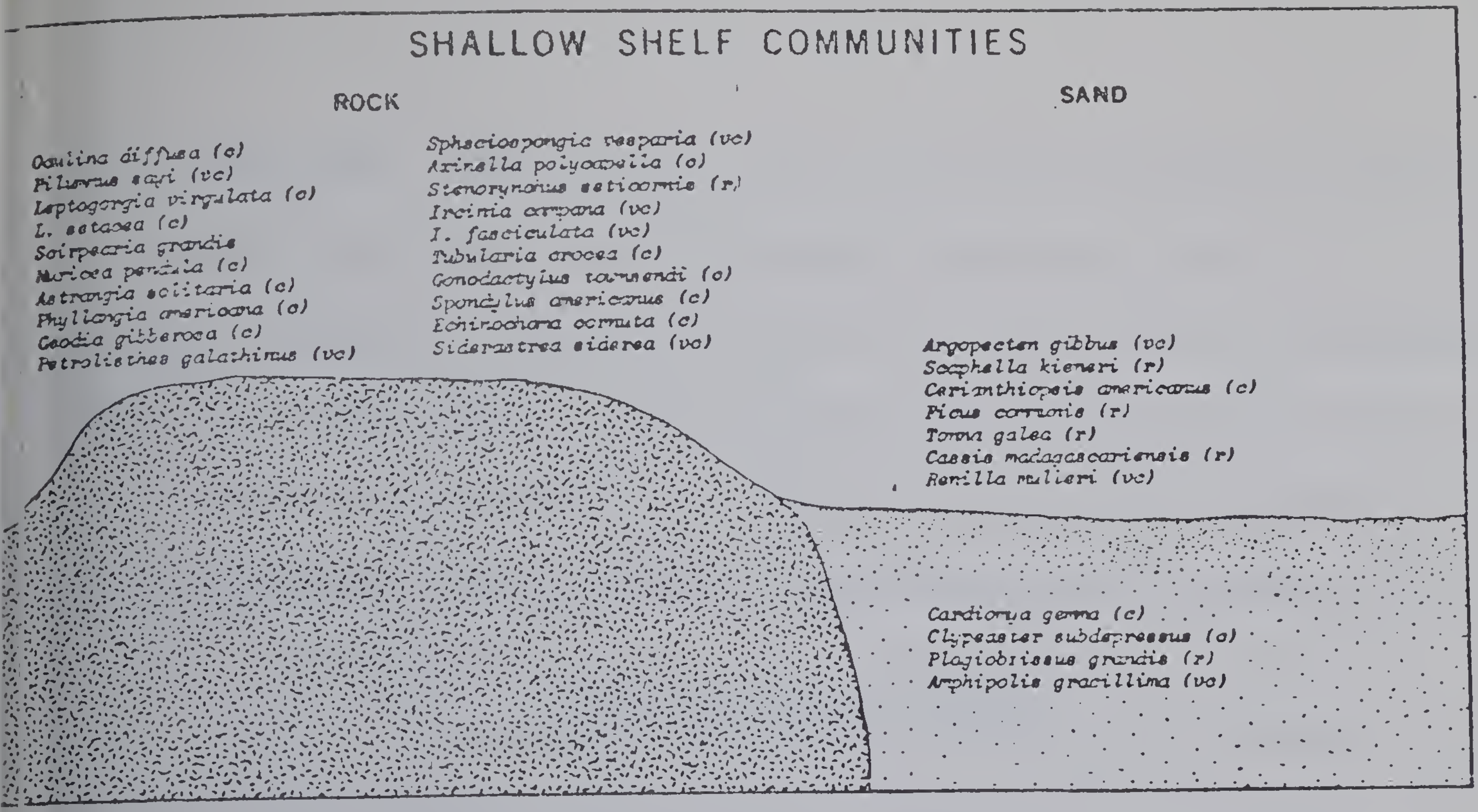
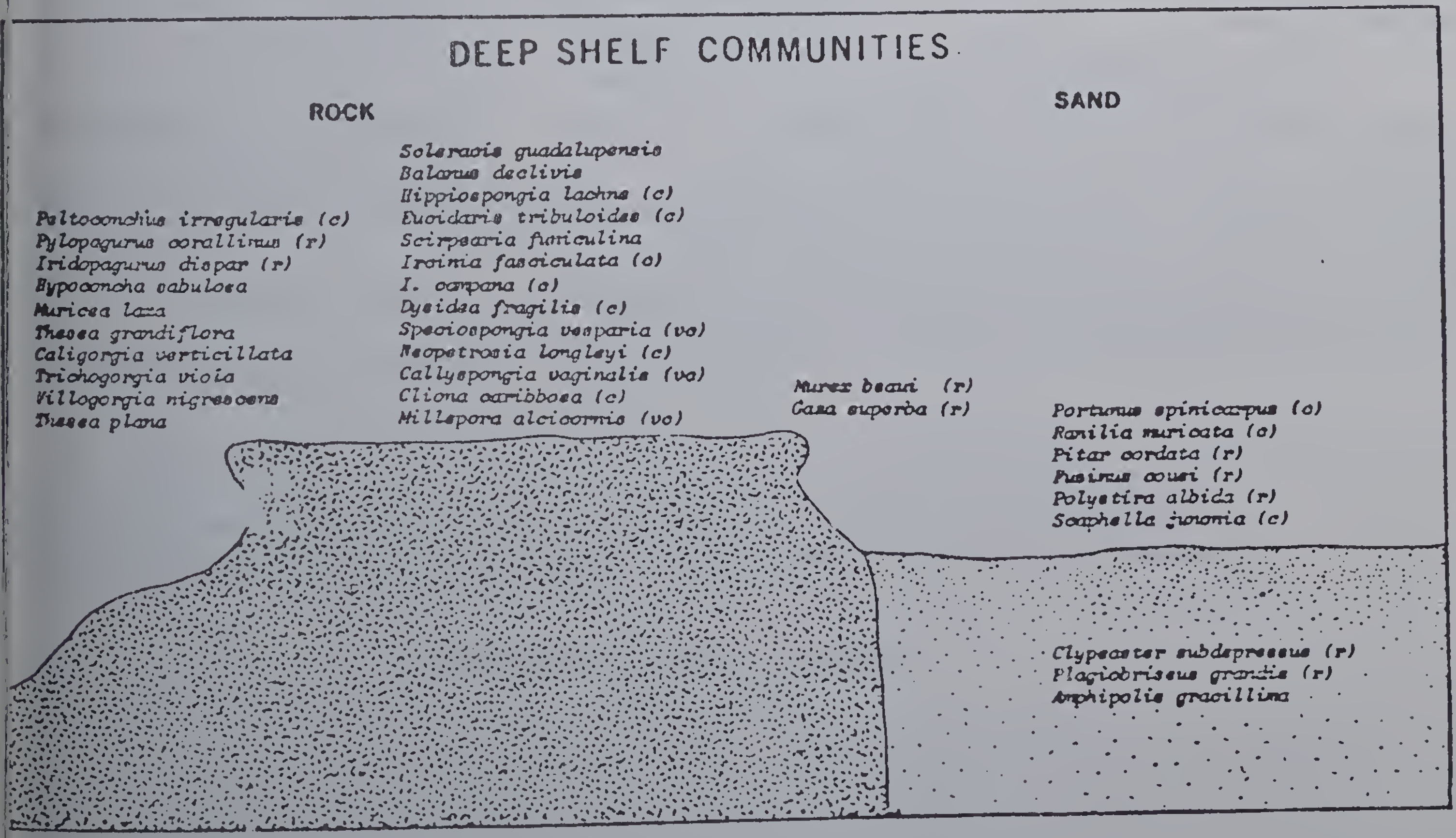


Figure 45. Shallow shelf communities: Carolinian affinities. These communities are continuous with the high energy beach and jetty communities and often contain the same species. (from Collard and D'Asaro, 1973)



igure 46. Deep shelf communities: West Indian affinities. Species occurring on the shelf exhibit strong West Indian affinities. (from Collard and D'Asaro, 1973)

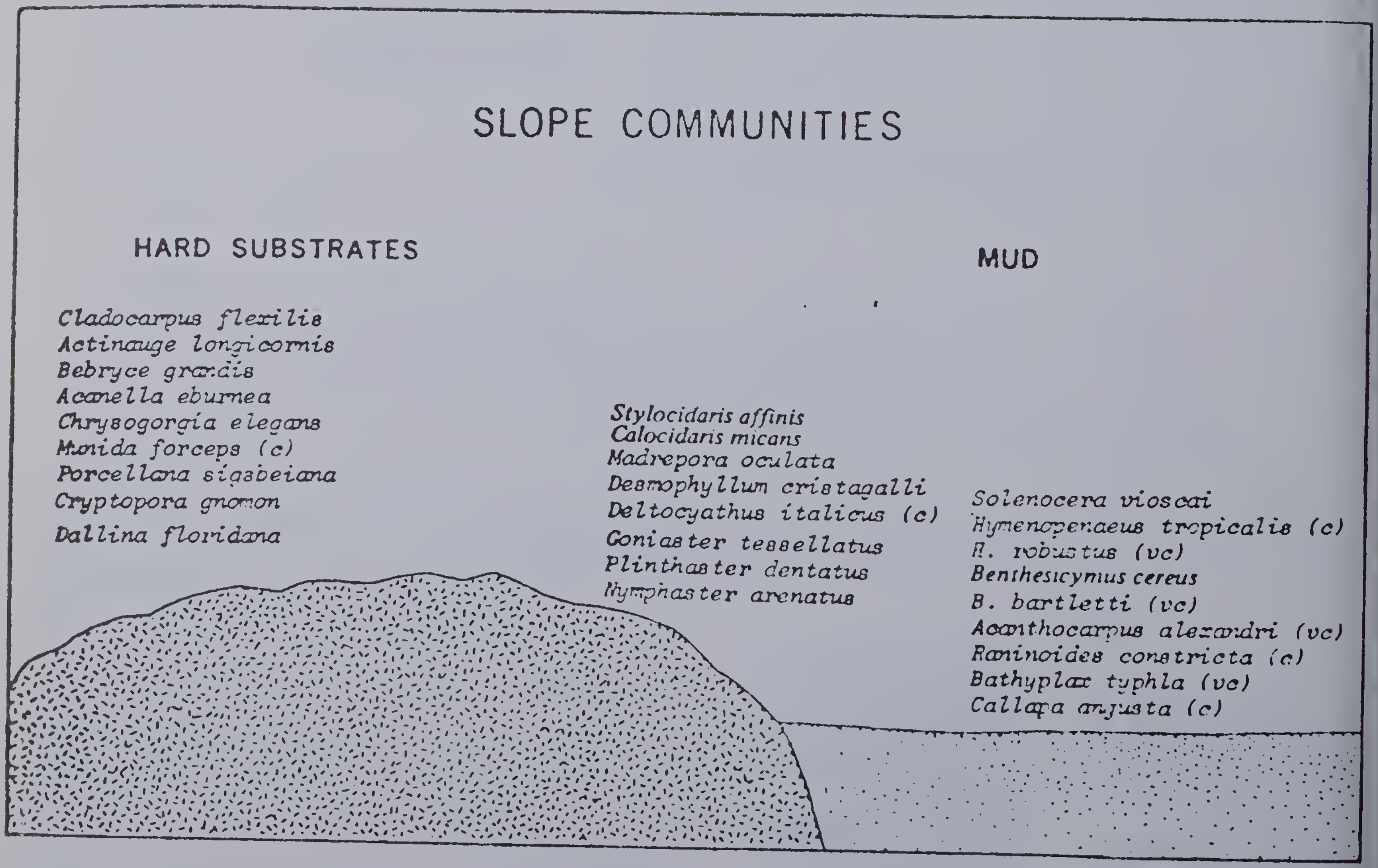


Figure 47. Slope communities. Many species found here are common throughout the Gulf of Mexico and are found in the Atlantic Ocean and the Caribbean Sea. (from Collard and D'Asaro, 193)

slope assemblages. They are but three of eleven assemblages described by these authors, the other being inshore communities which are discussed elsewhere. The diagrams illustrate differences in assemblage composition between hard and soft bottoms, and these differences within each diagram are probably more significant than the differences between diagrams. The differences between diagrams are depth and latitudinal differences, and the faunal assemblages were described by the authors as indicating Carolinian province (shallow shelf) and West Indian province (deep shelf) affinities.

Parker (1960) found that, for the bottom assemblages of Gulf of Mexico off the Texas and Louisiana coast, variations occur within the major associations according to sediment type. Assemblages living within silty clays in the intermediate shelf community are completely different in composition from those on sand bottom at the same depth. Certain species, however, bridge the two sediment types to create larger associations. Studies of the continental shelf in other parts of the world and in all oceans proved that the same basic assemblages listed here occupy similar depths in the same latitudes (Parker, 1960).

(4) Active Swimmers - Nekton

Organisms which remain suspended in the water and whose powers of locomotion are great enough to resist the set and drift of currents, being subject only to large-scale physical

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forces, are called nekton. Nekton for the offshore waters are represented by five major taxonomic categories - marine mammals and reptiles, the fishes, the cephalopod molluscs (octopuses and squid) and certain crustaceans (shrimp and swimming crabs). Individuals of this group commonly but not always, range over broad areas, thus participating in several biotic communities. For example, shrimps have a pelagic planktonic larvae, an estuarine juvenile and a pelagic adult. However, most nekton is limited in geographic and vertical ranges by the same environmental conditions as less mobile organisms, i.e., temperature, salinity, available food, and types of bottom.

The nektonic component of the environment can be divided into strictly open water nekton, and nekton which spend some portion of their lives in nearshore, estuarine, or marsh waters. Many of the finfish of commercial and sportfishing importance are strictly open water residents, such as the red snapper, various groupers, sailfish, and marlin. Of particular importance from commercial and sportfishing standpoints are the semi-catadromous species which spawn in open water, spend their early lives in fresh, brackish or estuarine waters, and return to deeper waters as adults.

Members in this group include the white, pink and brown shrimp, black drum and redfish, croaker, menhaden, southern flounder and spotted or sand seatrout. Mullet and pompano commonly inhabit nearshore areas throughout their lives.

Many organisms are demersal; that is, they have a particular habit of living on, or just above the sea bottom. Since distribution and abundance of demersal organisms is generally regulated by sediment type and the bottom communities that supply food, these organisms were more fully discussed in sections on the benthos and benthic communities.

Members of the nektonic assemblage ranging over broad areas of the pelagic environment include squid and the schooling fishes, such as the amberjack, crevalle jack, horseeye jack, bluefish, king mackerel, various anchovies and herrings, and menhaden. The anchovies, herrings, and menhaden are mainly planktivorous (feed on plankton) herbivores, feeding mainly on diatoms and dinoflagellates and rarely on zooplanktonic crustaceans (Rounsefell, 1954). Menhaden are of particular importance in that the menhaden fishery is the largest single fishery in the U.S. today, and most of the menhaden catch now comes from the Gulf of Mexico, primarily from the waters around the Mississippi delta (U.S. Army Corps of Engineers, 1973).

Several types of pelagic fishes do not travel in schools, but rather roam alone or in small groups. These types include the cartilaginous fish, the sharks, mainly bull, sharpnose, blacktip, mako, hammerhead and great white sharks, and the bony fish, such as Atlantic sailfish, blue marlin, dorado (dolphin fish), and cabio (ling or cobia). Most of these solitary or small school fishes are carnivorous, feeding on smaller fish, squid, chaetognaths, and other macroplankton.

Hildebrand (1954) described the fauna of the brown shrimp fishing grounds in the western Gulf of Mexico. The 10 most abundant fish are given in Table 18 . In addition, 38 other fish species of decreasing abundance were found.

Table 18.

TEN MOST COMMON FISHES (DECREASING ABUNDANCE FROM TOP) (After Hildebrand, 1954)

Prionotus rubio	Blackfin searobin
Trichiurus lepturus	Atlantic cutlassfish
Micropogon undulatus	Atlantic croaker
Syacium gunteri	Shoal flounder
Centropristis philadelphica	Rock sea bass
Cyclopsetta chittendeni	Mexican flounder
Synodus spp.	Lizardfish
Vomer setapinnis	Atlantic moonfish
Leiostomus fanthurus	Spot
Cynoscion nothus	Silver seatrout (weakfish)

Hildebrand (ibid.) characterized offshore shrimp ground communities by the dominant organisms; the brown shrimp *Penaeus aztecus*, the crab *Callinectes danae*, the pelecypod *Pitar cordata*, the conch *Busycon contrarium*, the starfish *Astropecten antillensis*, shoal flounders and butterfish. Inshore grounds are dominated by the white shrimp *Penaeus setiferus*, blue crab *Callinectes danae*, the sea pansy *Renilla mulleri*, the pelecypod *Pitar texasiana*, silver seatrout, Atlantic croaker, Atlantic threadfin, and sea catfish.

Data by James et al. (1972) from fish collections on the continental shelf in 1971 suggested a greater species diversity for the inner shelf and greater abundance on the outer shelf, with the intermediate shelf being intermediate in fish diversity and abundance (Table Catches on the inner shelf are seasonally quite variable and tend to be dominated by species which utilize the estuarine habitat in part of their life histories.

Certain oceanic fish visit the shelf waters during the summer months. These include the mackerels (Spanish, king, chub, frigate, and cero), bonito, tunny, amberjack, several jackfish (horseeye, bluntnose, crevalle, bar and yellow), as well as the blue runner, dolphin and a number of billfishes and other species of sport and commercial interest. These wide-ranging, fast-swimming predatory fishes are often caught within sight of shore, especially around the mouth of passes where they feed on anchovies, silversides, squid, shrimp, and bottom fishes.

(5) Birds

Available data pertaining to pelagic birds in the Gulf of Mexico does not allow more than a cursory treatment. There are apparently only a few species and most of these occur only in small numbers. The pelagic birds spend their entire life on the open waters of the sea except for returning to land to breed.

Table 19. Comparison of Trawl Fish Catches in Relation to Shelf Zone for the Upper and Central Texas Continental Shelf*

Shelf zone	Diversity (No. of spp.)	Abundance (No./Haul)	Dominant groups	Dominant species
inner shelf	61	161.9	searobins (26%) flatfishes (21%) drums (20%)	blackfin searobin (*Prionotus rubio*) spotted seatrout (*Cynoscion nebulosus*) Atlantic threadfin (*Polydactylus octonemus*)
intermediate shelf	48	245.1	flatfishes (45%) seabasses (20%) searobins (10%)	shoal flounder (*Syacium gunteri*) spotted whiff (*Citharichthys macrops*) blackear seabass (*Serranus atrobranchus*)
outer shelf	23	312.7	searobins (49%) lizardfishes (31%)	shortwing searobin (*Prionotus stearnsi*) largescale lizardfish (*Sauridia brasiliensis*) blackear seabass (*Serranus atrobranchus*)

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*By R. M. Darnell (Id. by C. Cashman). Most of the collections were made during the period May - July, 1971. Source: James et al., 1972.

Woolfenden and Schrieder (1973) discussed the pelagic bird populations of the Gulf. They suggested that the Wilson petrel is one of the few species of open Gulf waters that occurs regularly in fairly large numbers. Other species listed as occurring included gannets, jaegers and boobies. However, none are abundant and little is known concerning their distribution. Lowery (1960) described the species that had been recorded in Louisiana coastal waters. However, these were basically the same as reported above.

(6) Unique Environments

The northern Gulf of Mexico has many unique environments. These environments range from the nearshore features, i.e., the mangrove swamps of Florida, marshes of Louisiana, and beaches of Texas and Florida, to the offshore barrier islands of Mississippi and undersea reefs of Texas and Florida. A detailed discussion of the mangrove swamps, marshes, beaches, and barrier islands may be found in Section B.2.b.

Probably the most unique of all of these features are the undersea reefal features. The most prominent of these features are the Florida Middle Ground and the Flower Gardens (East and West) on the Texas OCS.

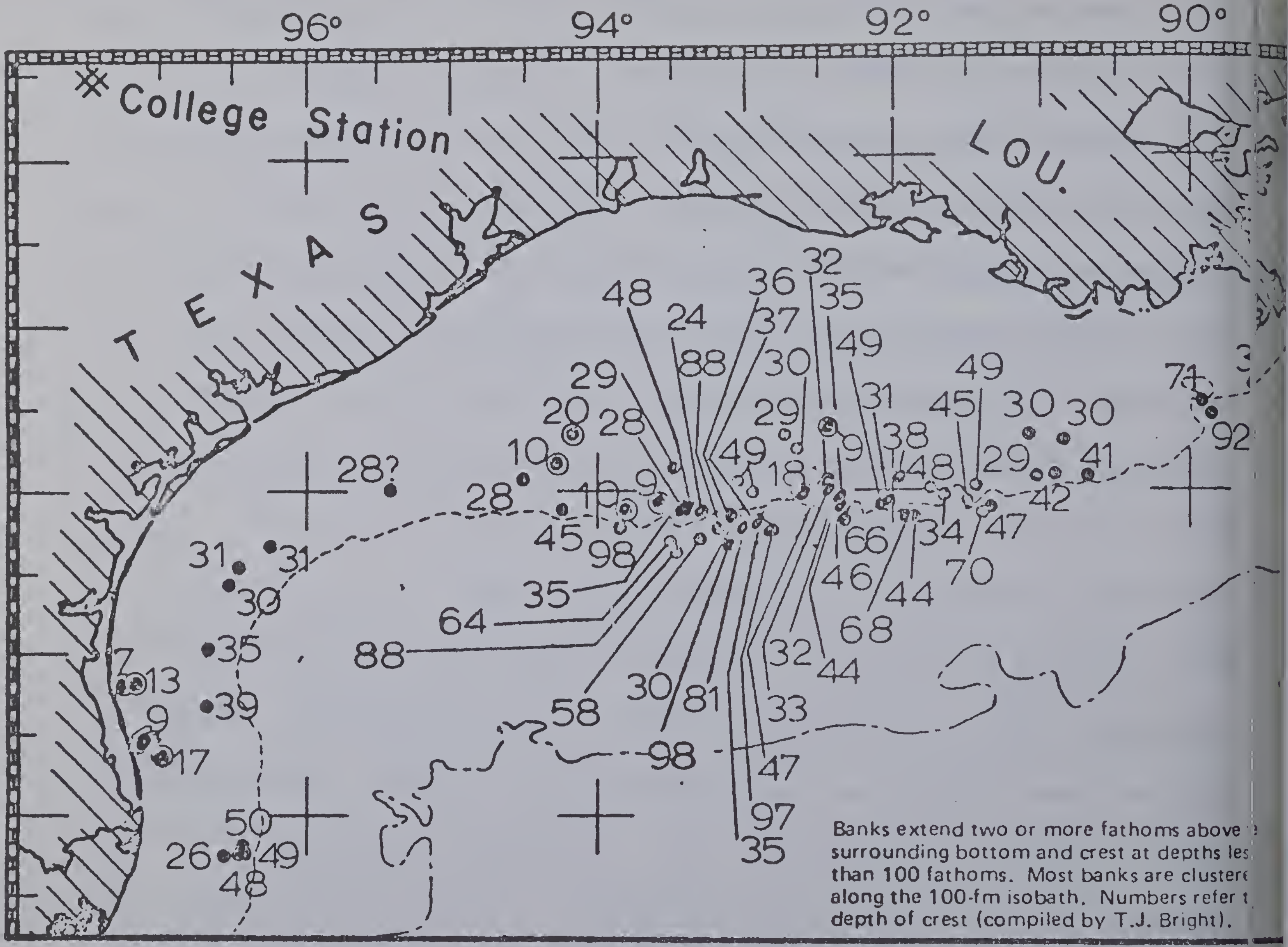
The Florida Middle Ground is an extensive area located along the barrier edge of the West Florida Shelf approximately 93 miles south of the northwest Florida coast and 100 miles northwest of Tampa. It is an area of steep-profiled escarpments and prominences, an area that is poorly defined in lateral extent by gradation of topographic and biotic features to the surrounding bottom and is a region of limestone outcrops on a drowned karst topography (Austin and Jones, unpublished ms.), the outcrops probably being Pleistocene reefs which flourished during the last interglacial, the Sangamon (Brooks, 1962). Depths throughout the region vary between 84 and 138 feet. Prominences may rise 36 to 48 feet above the surrounding bottom.

Certain physiographic, hydrological, and biological factors have allowed the development of a diverse biota dominated by tropical elements. Reef crests are covered with living invertebrates and benthic algae typical of deep-water West Indian reefs (Austin, 1970). Brooks (1962) noted the presence of living scleractinian corals (both hermatypic and ahermatypic), hydrocorals, alcyonarians (soft corals), and coralline algae.

The Flower Garden Banks are 2 topographic highs on the Texas OCS approximately 110 miles SSE of Galveston, Texas. The larger structure is West Flower Garden Bank and the smaller structure is East Flower Garden Bank. They were first identified in survey work by Coast and Geodetic Survey in 1936 (Shepard, 1937). Stetson (1953) suggested that the banks were capped by coral reefs, and Pulley (1963) reported these reefs to be live and flourishing.

The Flower Garden Banks are members of a series of pinnacles that rise abruptly from the smooth, sediment covered Outer Continental Shelf and slope off Texas and Louisiana. Figure 48 compiled by T. J. Bright, Texas A & M University, shows over 60 such banks with most of them clustered along the 100 fathom depth contour offshore of Western Louisiana and Eastern Texas. The origin of many of these pinnacles, and the Flower Gardens specifically, is the result of piercement salt domes, salt plugs which have thrust upward and warped and folded the overlying rock strata (Edwards, 1971). The West Flower Garden structure, at the edge where it rises from the seafloor, is approximately 7 miles long by 5 miles wide, trending northeast to southwest. Relief is about 300 feet, with water depth at the northern edge of the bank (landward) around 360 feet, and 450 feet at the southern (seaward edge). The uppermost point on the bank is 60-65 feet deep. The East Flower Garden structure is very similar, although smaller and more circular in shape, averaging about 3 miles in horizontal extent.

The flourishing coral reefs which cap these two banks are presently considered to be the northernmost thriving tropical shallow water coral reefs on the eastern coast of North America. They are apparently part of a discontinuous arc of thriving coral reefs and isolated hermatypic (reef-building) coral heads that ring the Gulf of Mexico harboring elements of the Caribbean reef fauna. Other



Banks extend two or more fathoms above
surrounding bottom and crest at depths les
than 100 fathoms. Most banks are clustere
along the 100-fm isobath. Numbers refer t
depth of crest (compiled by T.J. Bright).

Figure 48. DISTRIBUTION OF SUBMARINE BANKS IN THE NW GULF

hard banks in the northern Gulf (notably Stetson Bank and Three Hickey Rock) support coral type communities, but the coral are ahermatypic (non-reef-building), being mainly soft corals and hard encrusting milleporan type (fire coral).

e. Natural Phenomena Unique to Area with Potential to Cause or Contribute to Environmental Impacts of Proposed Action

Hurricanes and tropical cyclones present the greatest natural hazard in the Gulf of Mexico. The intensity of tropical cyclones may range from weak, barely noticeable but possibly developing areas of bad weather, to large and intense storms with maximum winds approaching 200 miles per hour (tropical cyclones with sustained wind speeds of 64 knots or greater are designated hurricanes).

All tropical cyclones which may affect the Gulf Coast area may be expected to originate within the Gulf of Mexico, the Caribbean Sea, or the southern part of the North Atlantic Ocean. The storm season extends from June to October with the greatest number occurring in August and September. During an average year, off the Gulf and Atlantic Coasts, there are fewer than ten tropical cyclones, of which about six develop into hurricanes. Over the last 10 years, these caused in an average year, the death of 50 persons between Texas and Maine, and property damage exceeding $400 million.

Deaths due to hurricanes were greatest in the Galveston area, 6000 deaths in 1900; in the Sabine Pass (Port Arthur) area, 390 deaths in 1957; and in the Corpus Christi (Brownsville) area, 287 deaths in 1919. Most of the damage and deaths along the Texas coast are due to flooding caused in the low lying areas by the surge of high waves as the hurricane approaches, rain upon impact on the area and flooding from rivers and local runoff in the storm aftermath. Serious flooding occurs up to the 20 foot elevation line which covers most of the coast and millions of acres of low lying ground inland. Although development may continue at a high rate along the low lying areas of the Texas coast, hazards from tropical storms and hurricanes compounded with projected land subsidence could decrease the feasibility of high growth.

The most severe hurricane in recent Gulf history was Hurricane "Camille" in 1969. During the onslaught of "Camille", one production platform was destroyed and two were damaged. Also in the area were seven drilling rigs that were not damaged. Total damage to the petroleum industry caused by "Camille" were estimated at $71.2 million, breakdown as follows:

Damage to fixed property (onshore)	$26,550,000
Damage to fixed property (offshore)	31,350,000
Damage to movable property	3,750,000
Other expenses (cleanup, evacuation, salaries)	3,650,000
Loss of Production	5,900,000
Total Losses	$71,200,000

When the Weather Bureau advises that a hurricane or serious tropical storm is imminent, all oil and gas facilities in, or adjacent to, the path of the storm are evacuated. Upon evacuation, all surface equipment and wellhead controls are shut-in. In addition, blank tubing plugs are set in as many wells as possible to further reduce the possibility of pollution in the event the well is damaged. These tubing plugs form a seal against fluid flow.

Of lesser importance in the Gulf of Mexico is the risk from earthquakes. No known damage has been recorded from earthquakes on an offshore oil platform or installation in the Gulf of Mexico.

Seismic risk is expressed in arbitrary numbers from 0 to 3. They are based on historical data considering only the intensity of an earthquake, not the frequency of occurrence, and express the anticipated damage that would occur in that area.

Zone 0 - No damage
Zone 1 - Minor damage
Zone 2 - Moderate damage
Zone 3 - Major damage

Most of central and all of southern Florida lie in an area where the occurrence of seismic hazards is extremely unlikely (Figure 11, Algermissen, 1969). Northern Florida and Western Mississippi lie in Zone 1 risk area which means that there is some danger of earthquakes of low intensity (ones which would not do damage to buildings). Small quakes have been reported in Central Florida, Gulfport, Miss. (1955) and three were reported in an area approximately 250 miles south of Pensacola, Florida. Because of the geological similarity

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of the land areas surrounding the Gulf and the adjacent continental shelf, one can reasonably extend the seismic risk zone boundaries some distance offshore.

In the map areas of the western Gulf of Mexico, seismic risk for the area is shown as zero (Algermissen, 1969). This appears to be a rather unique area due to the lack of seismicity. No earthquakes of any notable intensity have been recorded for this area and only two earthquakes of notable intensity have occurred in the Gulf near this area, neither of which produced damaging tsunamis nor were they considered well located events.

Complete assurance that a damaging earthquake will not occur in this area can never be made due to the fact that accurate locations and measurements of earthquakes is a fairly recent ability of the science. Three areas of zero seismic risk, i.e. southern Florida, western Florida, southern Alabama and Mississippi, and eastern Texas are shown on the NOAA Seismic Risk Map of the United States. Eastern Texas and the adjoining part of the Gulf of Mexico appear to be the most seismically quiet areas of the three zones.

3. Pacific Region

a. Geology

(1) Southern California and Santa Barbara Channel OCS

(a) General

The following discussion was abstracted primarily from Parker (1971) and text supplied by the U.S. Geological Survey.

The Southern California Borderland is a complex of basins, islands, banks, ridges and submarine canyons. The shelf edge, represented by the Patton Escarpment, is over 150 km from shore. The basins reach depths of over 2000 meters (San Clemente Basin-2107m) while the ridges and banks break the surface (Begg Rock).

Submarine canyons are present from the Mexican Border to the northern limit of the borderland, the Santa Barbara Channel. From south to north the major canyons are: the Coronado Canyon at the border, the La Jolla Canyon at the site of Scripps Institute, the San Pedro Valley in San Pedro Bay, and Redondo Canyon, Santa Monica Canyon, Dume Canyon, Magu Canyon and Hueneme Canyon all draining the Santa Monica Bay portion of the coastline into the Santa Monica Basin.

Depths at the base of the Patton Escarpment approach 4000m. Figure 49 depicts the major geomorphic features of the borderland area.

Subsurface

On the mainland coast, thick successions of upper Cretaceous sedimentary rocks are exposed in the Santa Ynez Mountains and Santa

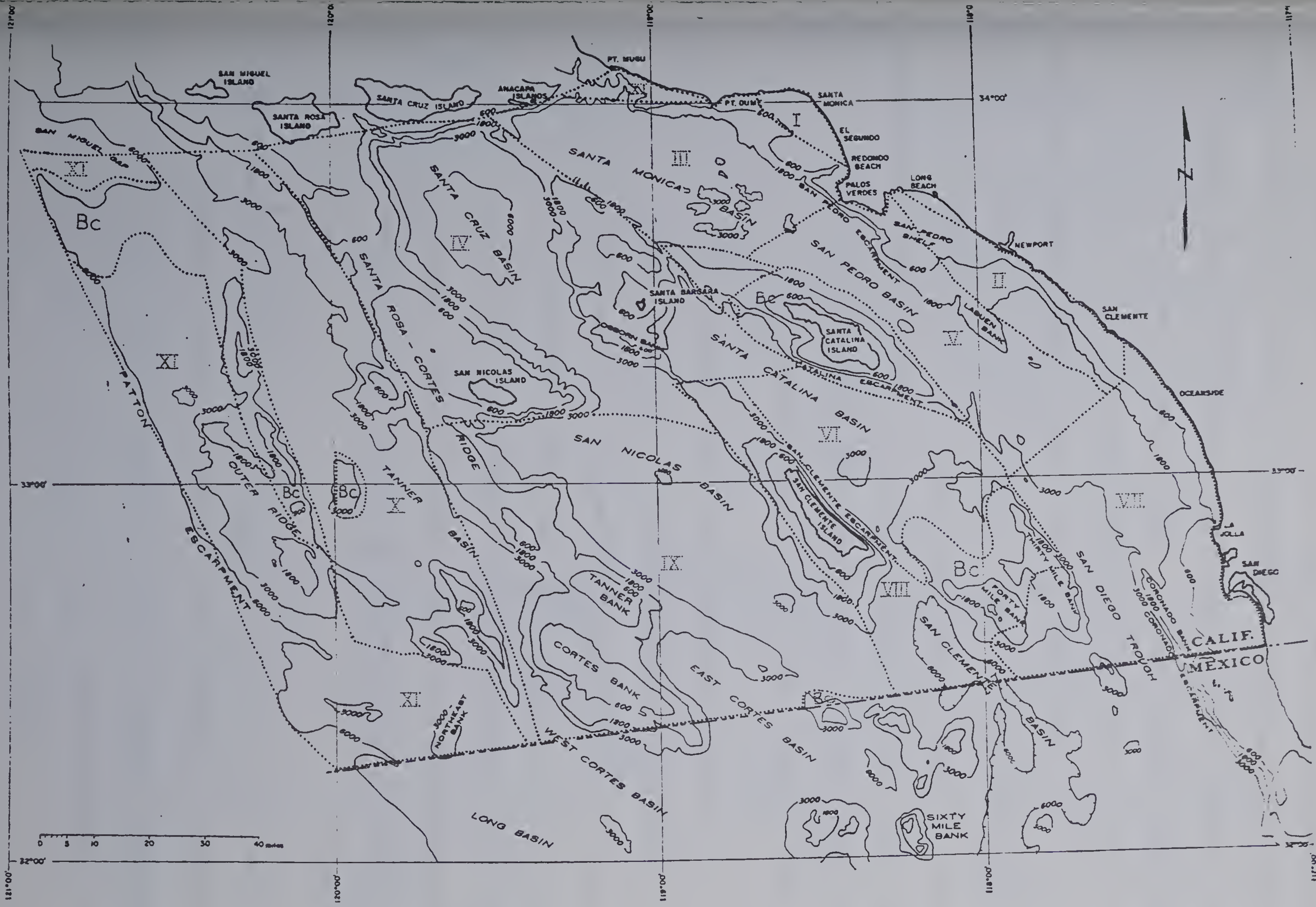

Figure 49. Geomorphic features of the Southern California Borderland (from Parker, 1971).

Monica Mountains, but their areal extent is relatively small. Correlative strata have been penetrated by wells on Santa Cruz Island, beneath the shelf north of San Miguel Island and beneath the east-central Santa Barbara Channel. The west end of San Miguel Island is the only place in the Channel Islands where there is an exposed section of Upper Cretaceous strata; there the sequence may be as much as 10,000 feet (3,050 m) thick. Structure sections (Fig.50) compiled by Curran et al. (1971) suggest that Cretaceous rocks underlie all parts of the Santa Barbara Channel, and may reach thicknesses of as much as 12,000 feet (3,660 m). Upper Cretaceous strata have not been reported from the islands south of the northern group.

Most of the Upper Cretaceous sequences in southern California consist of interbedded marine sandstone and mudstone beds that were deposited in a broad range of sedimentary environments. In general, Upper Cretaceous strata in the Santa Ynez Mountains and on San Miguel Island represent turbidite and deep sea fan deposits, whereas equivalent strata in the Santa Monica Mountains, Santa Ana Mountains and in the San Diego district are chiefly upper slope and shelf deposits.

Paleocene rocks are absent in the San Diego district and the Eocene shallow-marine sandstone and shale beds, including non-marine conglomerate lenses, are about 3,000 feet (910 m) thick. On San Miguel Island, Paleocene sandstone, shale, and conglomerate beds

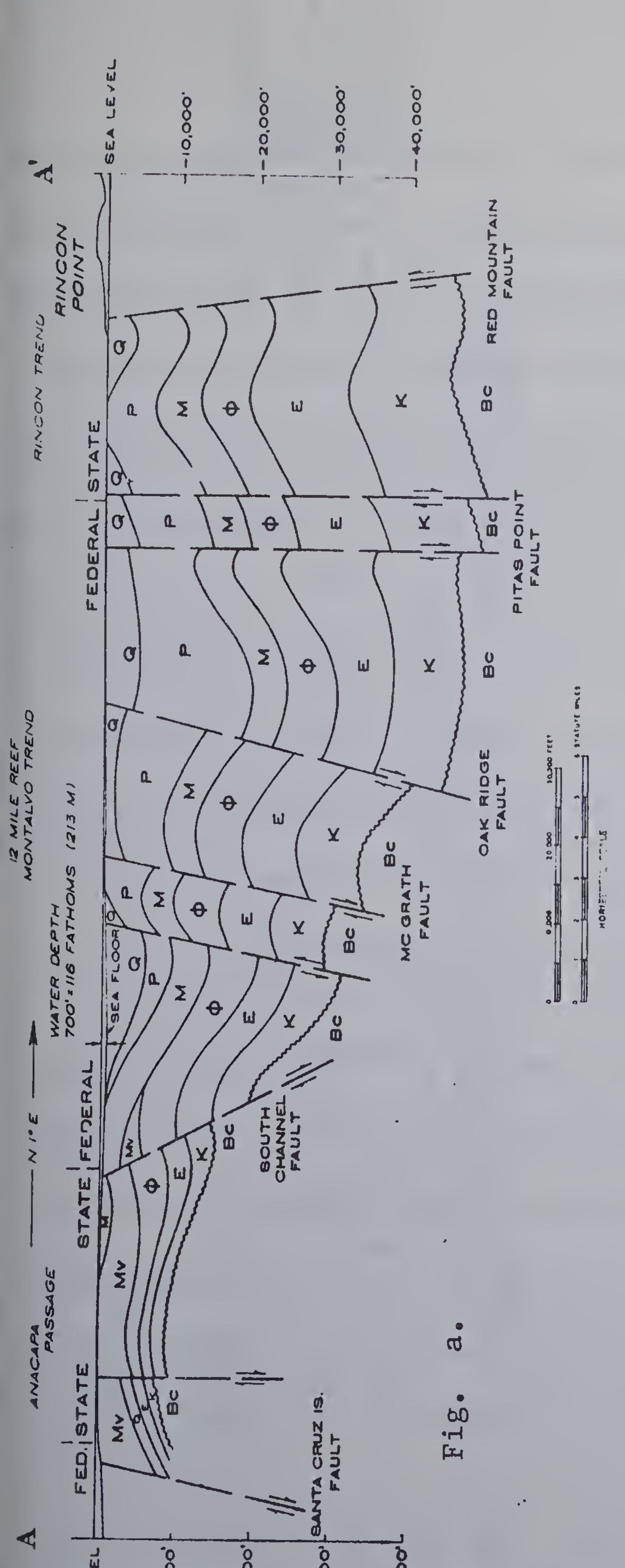

Fig. a.

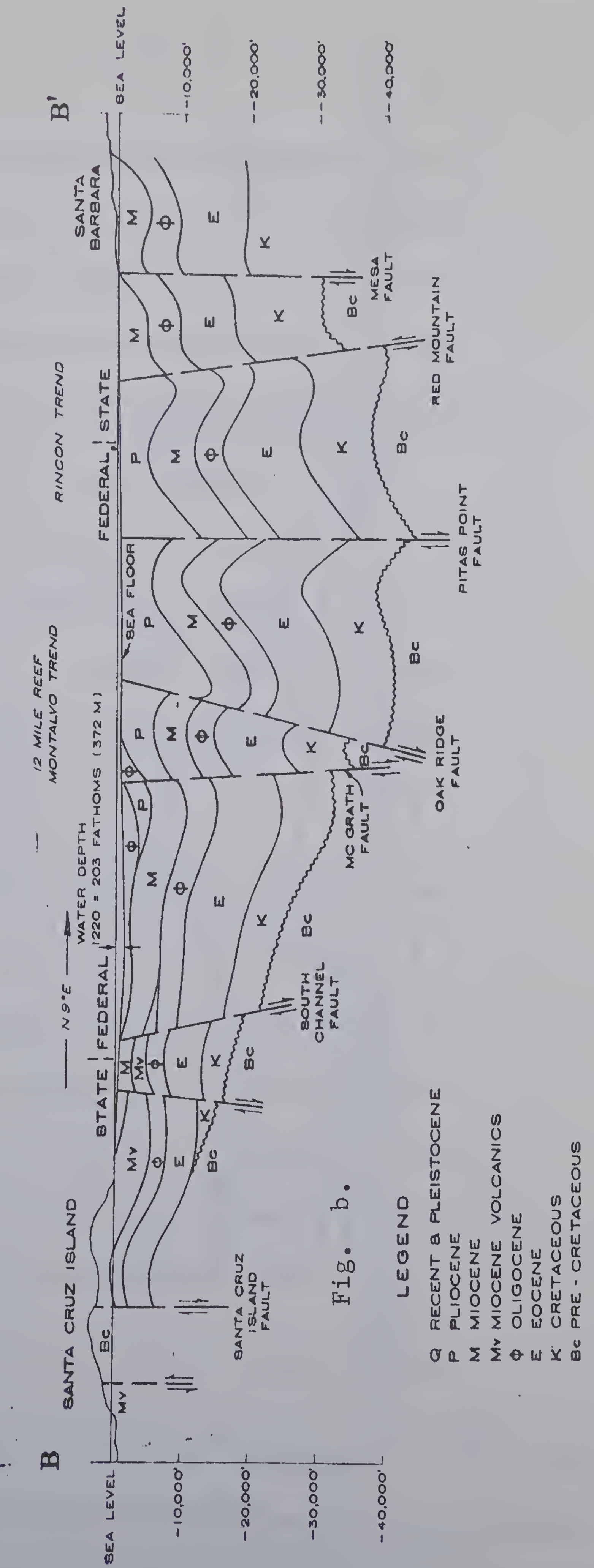

Fig. b.

Fig 50 Structural cross sections through the Santa Barbara Basin. A-A' is from Rincon Point to the Anacapa Passage while B-B' is from Santa Barbara to Santa Cruz Island. (from Parker, 1971).

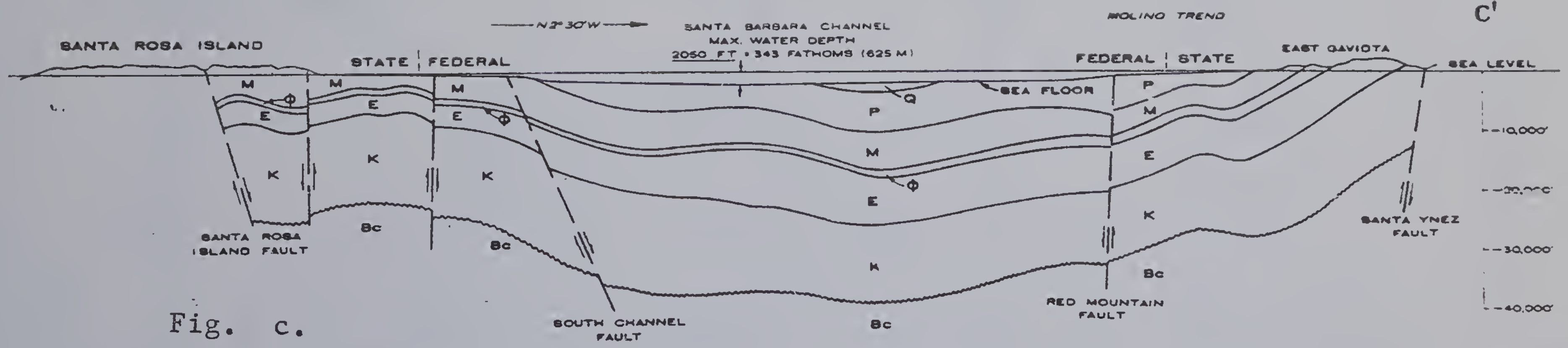

Fig. c.

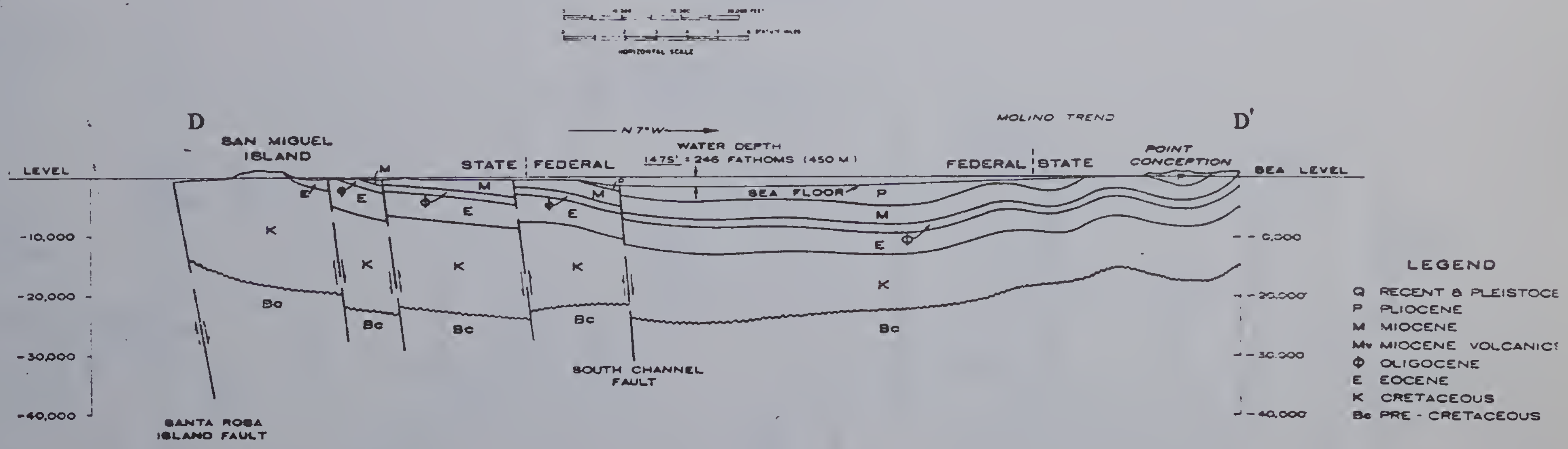

Fig. d.

Fig. 50. Structural cross section through the Santa Barbara Basin. Section C-C' is from Gaviota to Santa Rosa Island while D-D' is from Point Conception to San Miguel Island. (from Parker, 1971).

may be as much as 1,500 feet (460 m) thick and probably represent outer shelf and upper slope conditions of deposition. Less than 300 feet (90 m) of correlative shallow water deposits are exposed on Santa Cruz Island. Marine sandstone and shale beds of Eocene age that have a combined thickness of more than 4,000 feet (1,220 m) are present on and beneath the three large islands of the northern group. These strata reflect gradually deepening conditions of deposition through time. In the subsurface section beneath the Santa Barbara Channel, Eocene strata are thick, widespread, and probably continuous between the outcrops on the Channel Islands north and the mainland coast.

On the east and southeast sides of the Los Angeles basin, lower Miocene marine strata interfinger with non-marine beds to the north, however, toward the coast they rest gradationally on red beds and are increasingly finer grained as the section thickens in the same direction (Yerkes et al., 1965). Lower Miocene rocks are not known to be present in the area between the San Joaquin Hills and the Mexican border and on the southern group of islands.

Strata of middle Miocene age in coastal southern California are characterized by three petrologically distinct facies: an organic siliceous shale, a feldspathic sandstone, and a blue schist breccia and conglomerate. The siliceous shale and related rocks form one of the most widely distributed sedimentary facies along the coast; they are absent only from the Oceanside to San Diego area, Santa Catalina Island, and San Nicolas Island. These shaly strata are known to underlie large parts of the mainland shelf and are exposed on many of the island shelves, banks and ridges on the borderland. Less than 100 feet (30 m) of tuffaceous sandstone of possible late Miocene age overlies volcanic rocks on Santa Catalina Island. On the southern group of islands, volcanic rocks of middle Miocene age form most of Santa Barbara (Emery, 1960) and San Clemente Islands (Olmsted, 1958), but constitute less than one-third of the area of Santa Catalina Island (Bailey, 1941) and occur only as minor instrusions on San Nicolas Island (Vedder and Norris, 1963) and at Begg Rock. On San Clemente Island the flow sequence probably is more than 1,500 feet (450 m) thick.

Marine strata of Pliocene age generally are restricted to existing deep depositional basins and their closely adjacent margins. In the vicinity of Ventura, the Pliocene section is 15,000 feet (4,575 m) or more thick and may be more than 14,000 feet (4,270 m) thick in the central Los Angeles basin.

Thick accumulation of marine and non-marine deposits of Pleistocene and Holocene age are preserved at places along the mainland coast and in the interior basins (as much as 6,000 feet [1,830 m] east of Ventura). On the islands, these beds are limited chiefly to marine terrace deposits of late Pleistocene age and dune and slope-wash cover of Holocene age.

A structural relief of about 20,000 feet (6,100 m) on the basement surface between the axial part of the San Nicolas Basin and Santa Catalina Island is judged to be a maximum for the northern part of the borderland (excluding the Santa Barbara Channel), although there seems to be an equal amount of relief between the trough of Santa Cruz Basin and the top of Santa Cruz Island. These estimates do not approach those for the Ventura and Los Angeles Basins, where the structural relief is nearly 60,000 feet (18,300 m) and more than 40,000 feet (12,200 m), respectively. On the Patton Escarpment there may be on the order of 12,000 feet (3,660 m) difference between the basement surface on Patton Ridge and the acoustic basement that lies beneath the base of the continental slope.

Highly interpretive structure sections (Fig.51) published by Parker (1971) suggest that the major folds on the outer part of the borderland are very broad and nearly symmetrical in contrast to typical structures in the Ventura and Los Angeles Basins where tight, steep-limbed, asymmetric en echelon folds are commonplace. Seismic profiling records recently taken by the U.S. Geological Survey across the northern part of the Santa Rosa-Cortes Ridge confirm the presence of a large, broad anticlinal structure that is steeper on its western flank; superimposed on it are several folds with much smaller amplitudes. Similar small folds underlie the southeast end of the same ridge system at Tanner

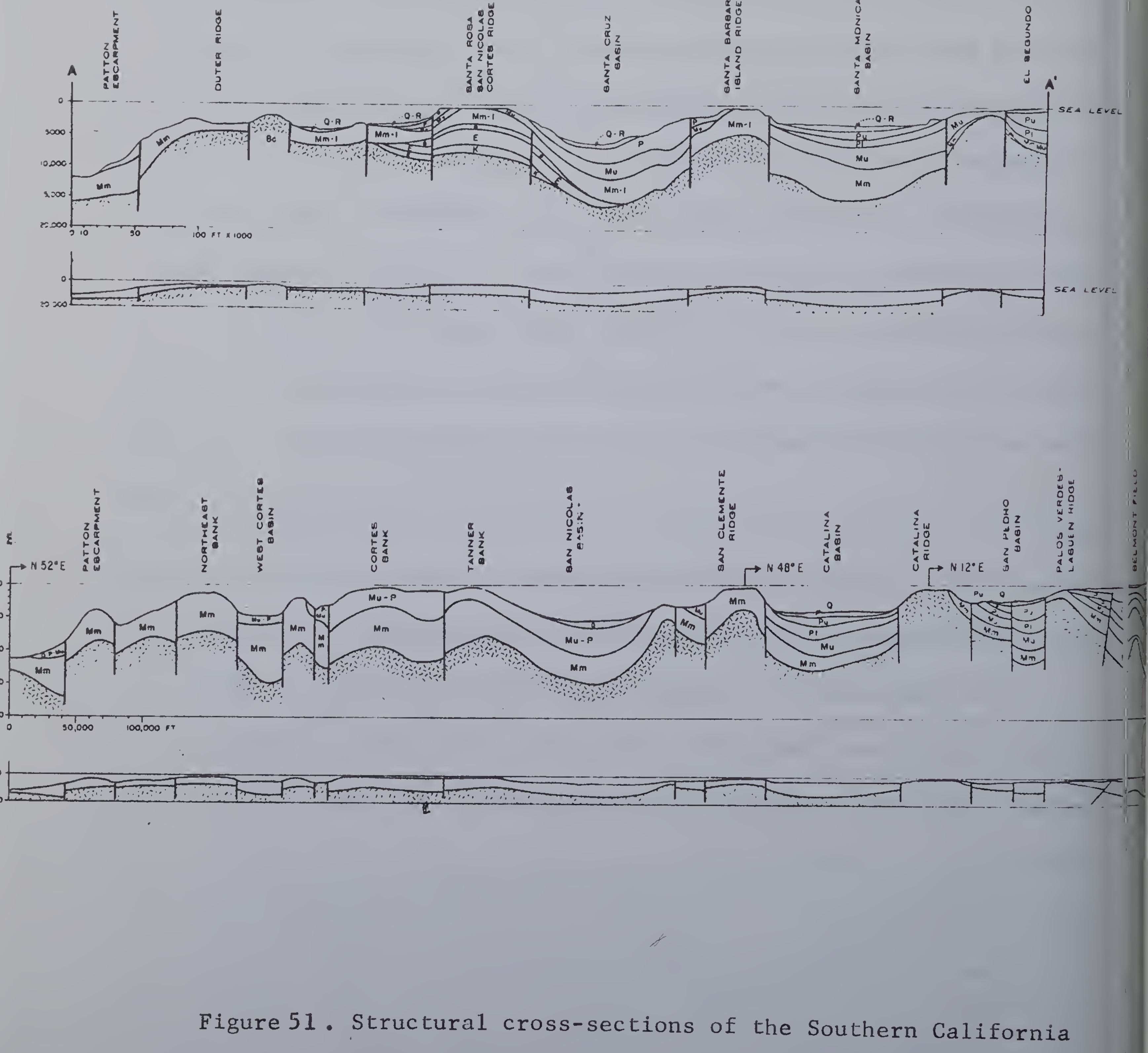

Figure 51. Structural cross-sections of the Southern California Borderland off El Seguendo and Long Beach. The upper section in each pair has a 5X vertical exaggeration; the lower, none. (from Parker, 1971).

and Cortes Banks and in the northern part of the San Nicolas Basin. Other areas that seem to have local folds are Patton Ridge and the ridge between Osborn Bank and Santa Cruz Island.

Seaward of the islands the dominant fault trend is northwest, but a few east-trending cross faults are depicted by most published sources. From west to east, inferred northwest-oriented traces with the greatest length are those that form 1) the Patton Escarpment, 2) the west edge of the Santa Rosa-Cortes Ridge, 3) the east and west margins of the Santa Cruz and San Nicolas Basins, and 4) the San Clemente Basin. Earthquake epicenters on the borderland, although poorly located and less densely distributed than on the mainland, suggest recent activity associated with some offshore faults, particularly the San Clemente Island-Agua Blanca fault system.

(b) Hydrocarbon Potential

A discussion of petroleum potential offshore southern California relys heavily on present knowledge and development of presumably analagous onshore regions such as the Ventura, Santa Barbara and Los Angeles Basins. Published descriptions of offshore rock sections suggest that a number of the shaly or silty units ranging in age from late Cretaceous to late Miocene contain sufficient carbonaceous or other organic matter to constitute potential source rocks for petroleum. Whether or not the deformational and thermal history of any of these units has been appropriate for the genesis and escape of fluid hydrocarbons is not known.

Santa Barbara Channel

The Santa Barbara Channel has the best known petroleum potential of the Pacific OCS areas. Over 30 producing oil and gas fields have been identified in this area (Fig. 53). Fields producing through 1970 are listed in Table 20. Through 1972, the Santa Barbara Channel area had produced 1.3 billion bbl. of oil and over 3 trillion cubic feet of gas, or 8 and 10 percent, respectively, of total State production during the same period (U.S. Geological Survey, 1974). All current production occurs from strata ranging in age from Cretaceous through Tertiary.

With respect to future petroleum potential, the continuation of favorable onshore stratigraphic and structural trends has been confirmed offshore. Fractured marine shales and numerous potential structural traps have been identified along with thick sandstone sections that offer good reservoir capabilities.

(c) Geologic Hazards

The following text discusses potential geologic hazards for all California OCS areas.

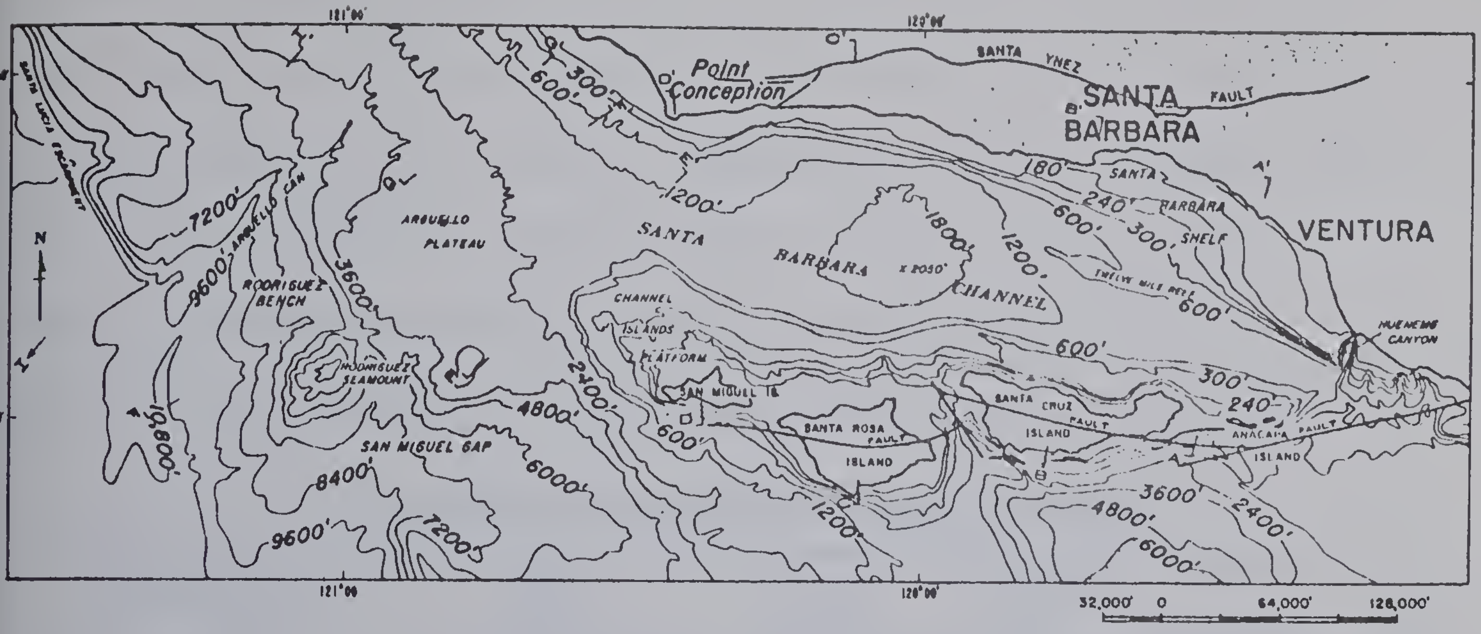

Figure 52. Physiography of Santa Barbara Channel area (from Curran, et al., 1971).

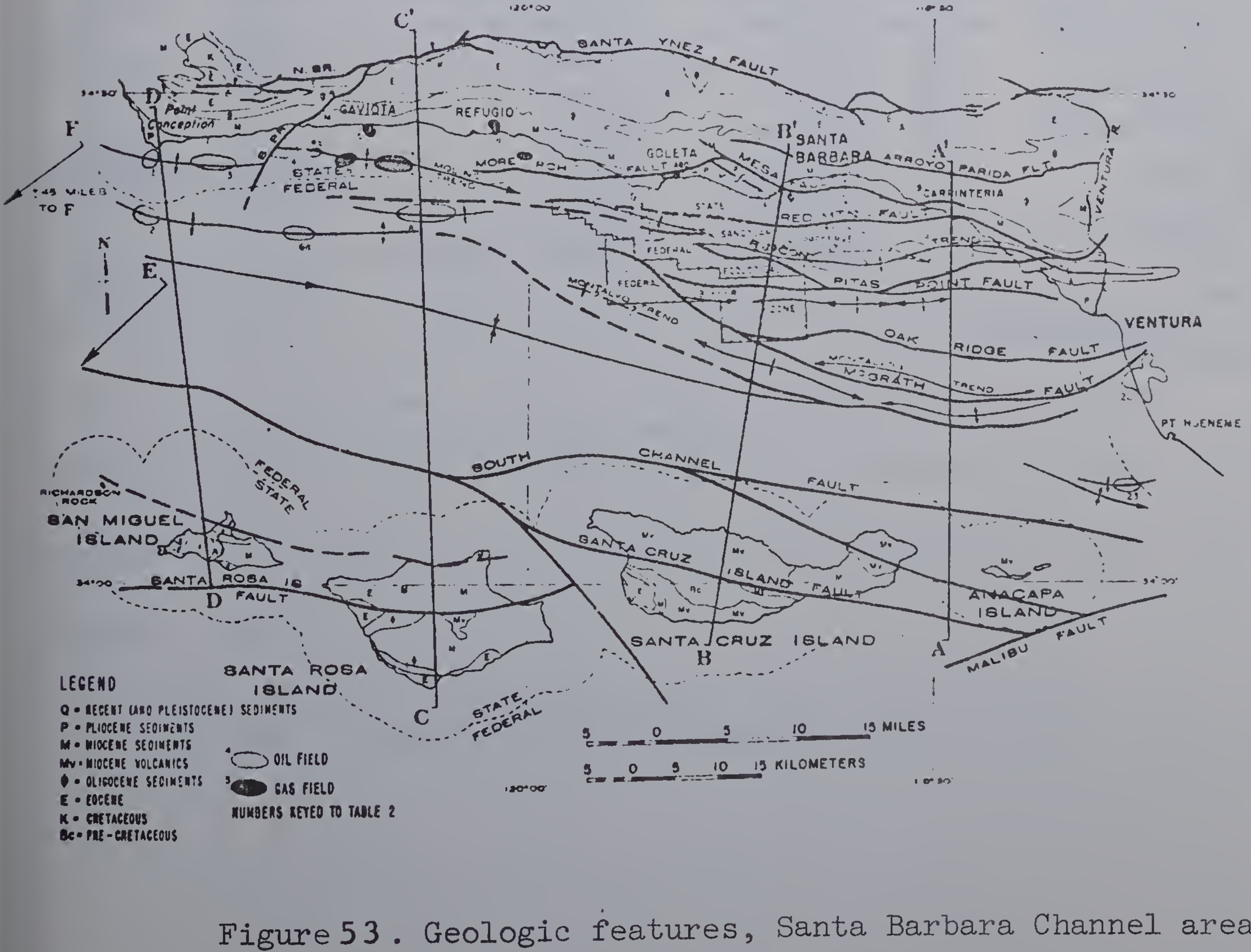

Figure 53. Geologic features, Santa Barbara Channel area (from Curran, et al., 1971).

Table 20, Oil and Gas Fields, Santa Barbara Channel Area

Map No.	*Field Name*	*Discovery Date*	*Producing Formation*	*Age of Producing Formation(s)*	*Cumulative Production to Jan. 1, 1970. .*	
					(M bbl)	*(Mcf)*
1	Pt. Conception Offshore	1965	Alegria-Vaqueros	Oligocene-Miocene	155	46
2	Unnamed	1969	?	?	——	——
3	Conception Offshore	1961	Alegria[1]	Oligocene	19,726	12,933
4	Cuarta Offshore	1961	Alegria	Oligocene	600	6,641
4a	Alegria Offshore	1962	Alegria-Vaqueros	Oligocene-Miocene	154	2,497
5	Gaviota Offshore (gas)	1960	Vaqueros	E. Miocene	——	62,547,391
6	Caliente Offshore (gas)	1962	Vaqueros	E. Miocene	——	22,576,680
6a	Unnamed	1970	Monterey	M. Miocene	——	——
7	Molino Offshore (gas)	1962	Sespe-Vaqueros	Oligocene-Miocene	——	164,229,348
8	Unnamed	1969	Monterey?	M. Miocene?	——	——
9	Capitan	1929	"Coldwater"-Sespe-Vaqueros	Eocene-Oligocene-E. Miocene	19,081	14,903
10	Naples Offshore (gas)	1960	Vaqueros	E. Miocene	——	20,814,928
11	Elwood	1928	Sespe-Vaqueros	Oligocene-E. Miocene	102,988	85,563
12	South Elwood Offshore	1966	Vaqueros-Rincon	E. Miocene	3,993	5,272
13	Coal Oil Point Offshore	1948 & 1961	Sespe-Vaqueros	Oligocene-E. Miocene	1,076	2,743
14	Mesa (ABD)	1929	Vaqueros	E. Miocene	3,735	8
15	Summerland (ABD)	1877	Pico-Sta. Barbara	Pliocene	3,210	——
16	Summerland Offshore	1958	Vaqueros	E. Miocene	21,845	71,151
17	Dos Cuadras Offshore	1968	Repetto	Pliocene	?	?
18	Carpinteria Offshore	1966	Repetto-Pico	Pliocene	20,359[2]	14,035[2]
19	Rincon	1927	Repetto-Pico	Pliocene	102,430	157,225
20	San Miguelito	1931	Repetto-Pico	Pliocene	54,222	155,937
21	Ventura	1917	Repetto-Pico	Pliocene	740,658	1,929,862
22	West Montalvo	1947	Sespe-Vaqueros & Repetto	Oligocene, E. Miocene & Pliocene	30,078	20,715
23	Unnamed	1969	Sespe-Vaqueros	Oligocene-E. Miocene	——	——
	Totals				1,124,310	272,647,878

[1] Also called "Sespe equivalent."
[2] State lands only.

(from Curran, et al., 1971).

Potential geologic hazards to oil and gas resource development offshore California involve primarily the irregular subsea topography and recurring activity along the complex fault systems of the area. This fault activity is a manifestation of large-scale crustal movements that are occurring along the entire western coast of North and South America, as well as in other parts of the world. The unifying concept that relates these worldwide phenomenon (Plate Tectonic theory) will be discussed under Alaskan Geology, section II.A.4.a. Other potential hazards along coastal California include mass wasting (landslides, slumps, creep), ground surface erosion, onshore flooding, land subsidence, and expansive soils. Submarine topography has been discussed previously; remaining hazards are discussed below, as abstracted from California Division of Mines and Geology (1973).

Fault Displacement

A fault is a fracture in the crust of the earth along which there has been movement or displacement. Active faults are the main sources of earthquakes. Land use planners should consider the possible future effects of fault movement in conjunction with the placement and design of new structures. Two aspects of fault displacement should be considered:

1. The effects that sudden displacement along faults may have on structures built across their traces.

2. The relatively slow effects of fault creep--the gradual ground distortion and movement along a fault trace not accompanied by significant earthquakes.

Fault displacements involve forces so great that the only means of limiting damage to man-made structures is to avoid areas along traces of active faulting or to design structures to accommodate the expected displacement.

The present state-of-the-art is such that active faults can be identified and located through detailed geologic mapping, seismic study, trenching, drilling, and geophysical work. Although this work may be expensive, it is possible to locate most active faults accurately and thereafter guide development so that losses due to fault displacement on known active faults can be virtually eliminated.

Earthquakes

The California Division of Mines and Geology (1973) published a preliminary seismic risk map (Fig.54) which categorizes the State into three zones of maximum earthquake intensity and probable damage. Virtually all of the coastal areas lie within zones II and III signifying moderate to major potential structural damage.

Mass Wasting

Mass wasting involves the downslope movement of masses of earth material under the influence of gravity. Movement may be rapid

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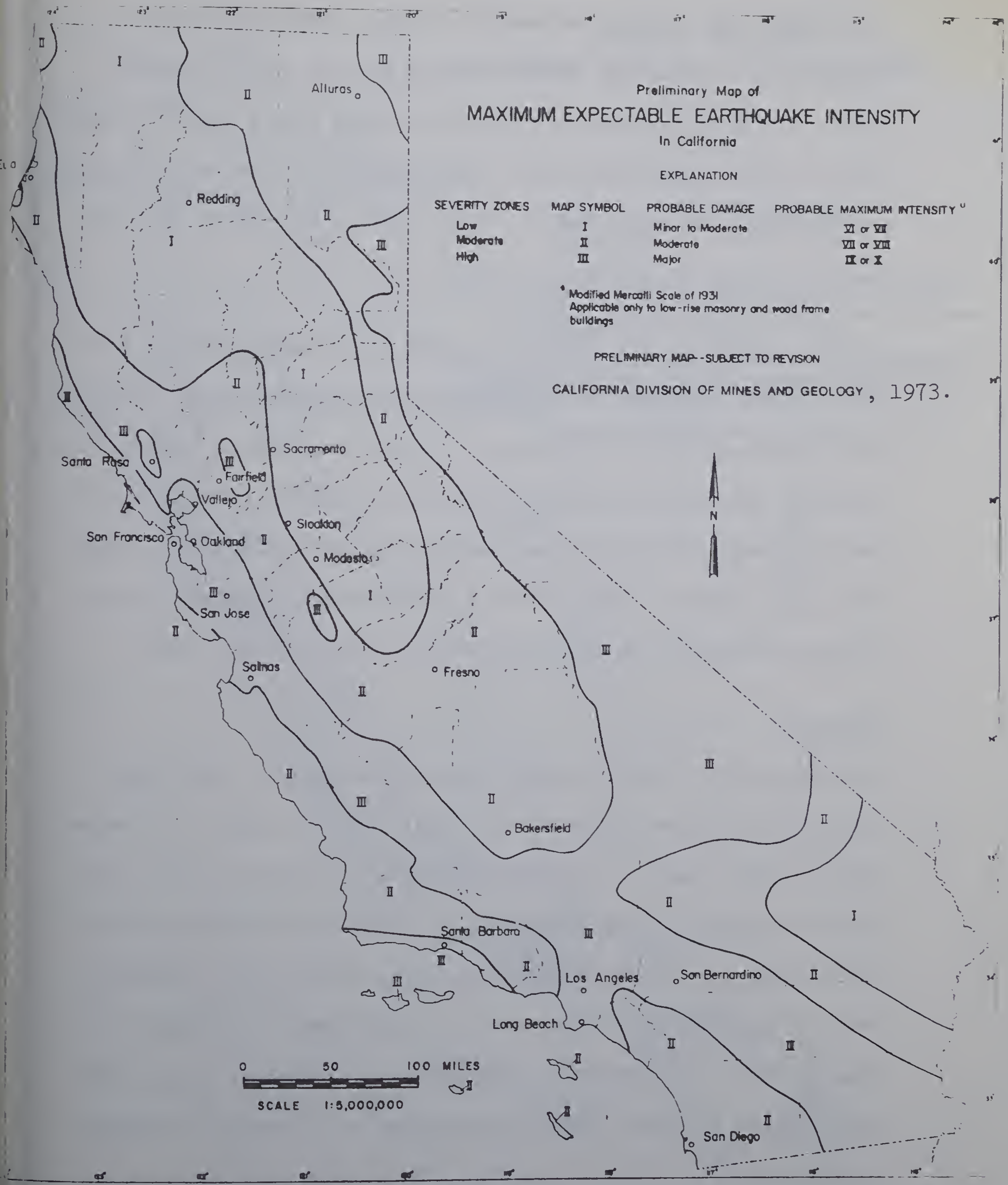


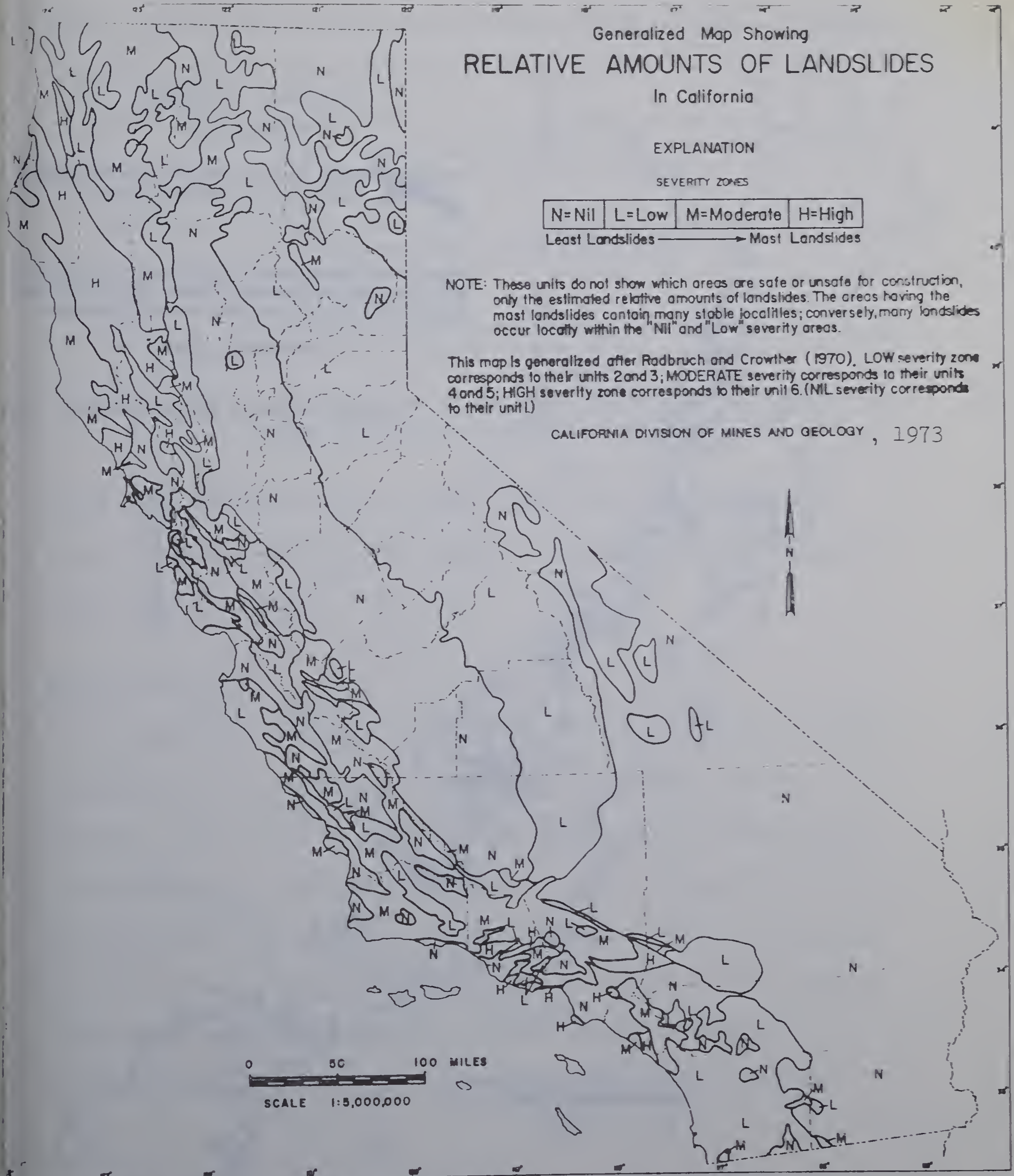
ure 4, Preliminary map of maximum expectable earthquake intensity in California.

(landslide) or so slow (creep) that a change of position can be noted only over a period of weeks or years. The areal size of a landslide can range from several square feet to several square miles. Slide thicknesses may range from less than a foot to several hundred feet. Landslides are a common problem in the hillside areas of California and, in terms of dollar losses, are one of the most costly geologic hazards (Figure 55.)

One of the more notable slides occurred at Portugese Bend on the Palos Verdes peninsula in southwestern Los Angeles County. An old slide was reactivated in 1956 on a 170 acre section of land extending from near the western summit of the Palos Verdes Hills down to the Pacific Ocean. This slide has damaged or destroyed more than 200 homes. In February 1973, in the area of maximum movement, slide movement continued at an average rate of one foot per month.

Flooding

Flooding is one of the costliest natural hazards in California. National statistics show that California ranks as one of the major flood problem areas in the Nation and that flooding is one of the principal factors to be considered in the overall development and use of land resources. Although existing flood control measures have, in general, been effective in controlling or reducing flood damaged, flood problems have nonetheless continued to grow. The distribtuion of areas subject to flooding in California is shown in Figure 56.



NOTE: These units do not show which areas are safe or unsafe for construction, only the estimated relative amounts of landslides. The areas having the most landslides contain many stable localities; conversely, many landslides occur locally within the "Nil" and "Low" severity areas.

This map is generalized after Radbruch and Crowther (1970). LOW severity zone corresponds to their units 2 and 3; MODERATE severity corresponds to their units 4 and 5; HIGH severity zone corresponds to their unit 6. (NIL severity corresponds to their unit I.)

CALIFORNIA DIVISION OF MINES AND GEOLOGY, 1973

55, Generalized map showing relative amounts of landslides in California.

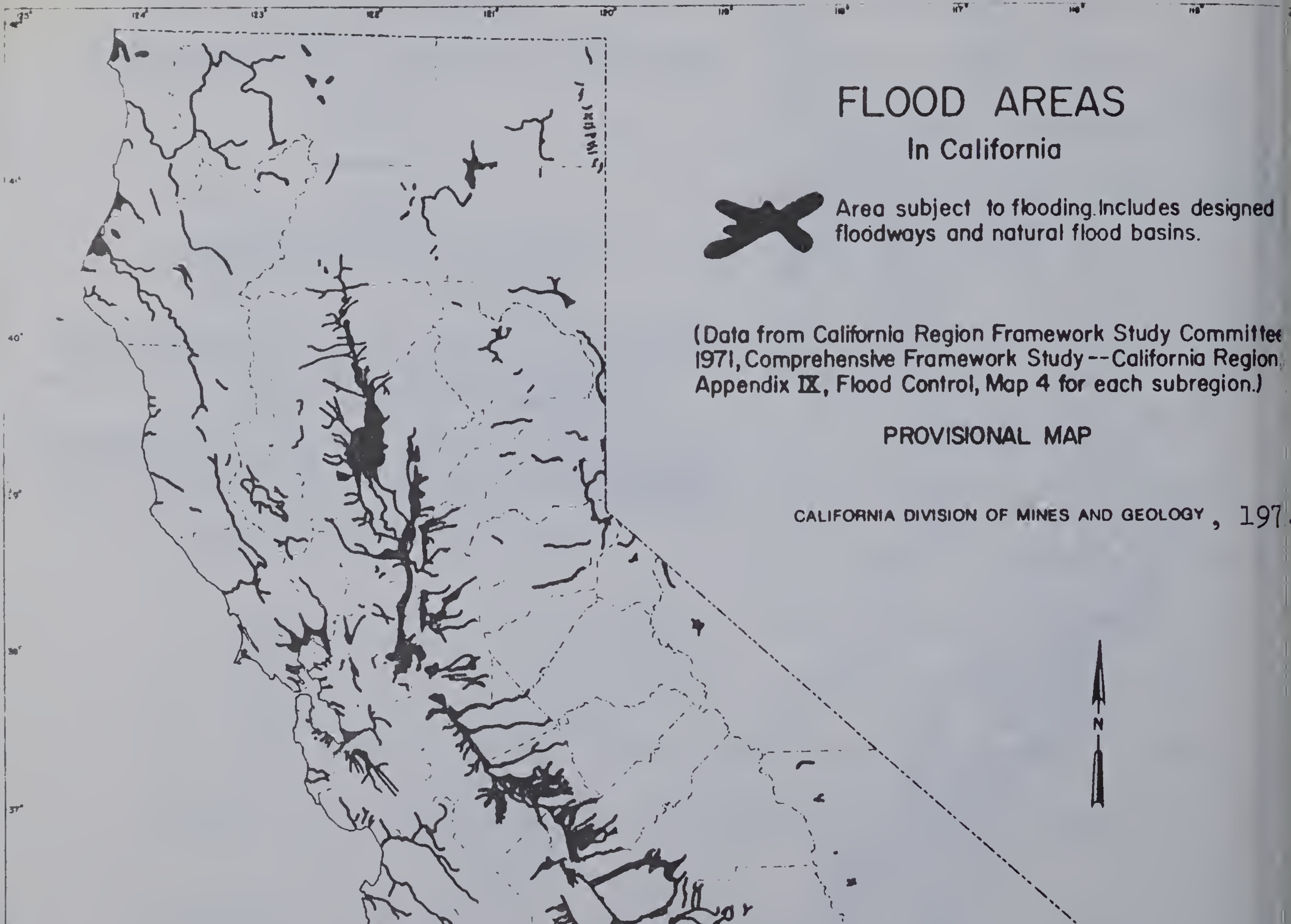

FLOOD AREAS
In California
Area subject to flooding. Includes designed floodways and natural flood basins.
(Data from California Region Framework Study Committe
1971, Comprehensive Framework Study--California Region
Appendix IX, Flood Control, Map 4 for each subregion.)
PROVISIONAL MAP
CALIFORNIA DIVISION OF MINES AND GEOLOGY, 197
N
0 50 100 MILES
SCALE 1:5,000,000

Figure 56. Flood areas in California.

Between 1770 and 1950, 23 major floods have been recorded at various locations in the State, claiming 144 lives in the 50 years from 1900 to 1950. The greatest of these were:

1805 - The inundation of the entire floor of the Great Valley, causing great loss of life and destruction of Indian villages.

1861-62 - The inundation of the Great Valley, the Los Angeles Basin, and other areas in the State.

1907 - The flooding of northern California and the Great Valley.

1909 - The flooding of northern California and over 300,000 acres in the Great Valley.

Since 1950 there have been 11 major floods with the loss of 222 lives and extensive damage to property (California Region Framework Study Committee, 1971).

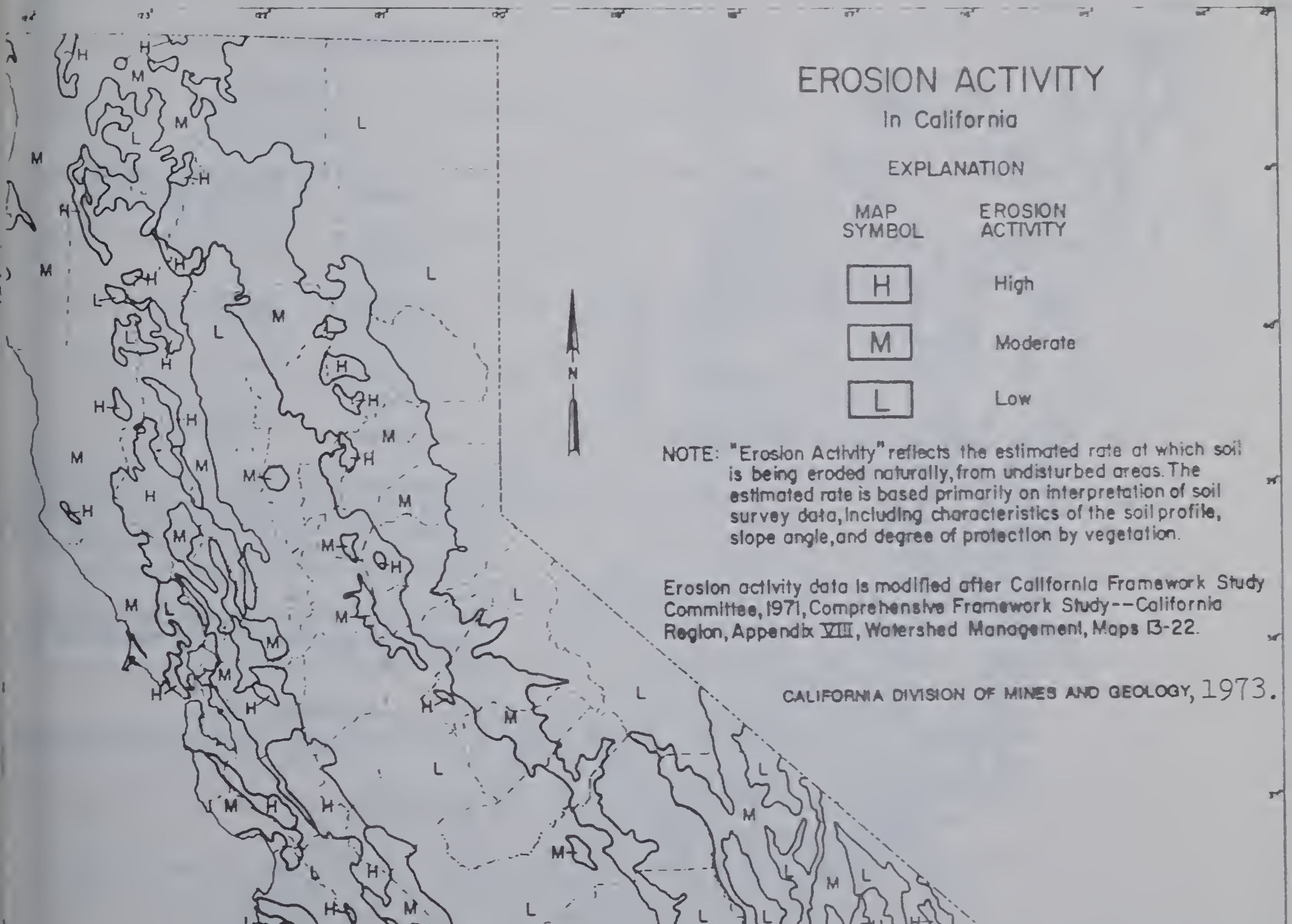
Erosion Activity

Erosion generally involves two somewhat distinct problems--the wear and removal of material from one site and its disposition at another. The removal of soils through erosion can be damaging in situations of sheet and gully erosion of land surfaces, the wind-blown denudation of land, the erosion of stream courses and banks, and the erosion of coastal cliffs, dunes and beach areas. Deposition damage affects flood plains, rivers, lakes, reservoirs, and may clog drainage structures. Activities by man may frequently accelerate erosional phenomena. Figure 57 depicts the relative rate of erosion in California. It should be noted that the majority of the coastal zone is characterized by low to moderate erosion activity.

Expansive Soils

Expansive soils are earth materials which greatly increase in volume when they absorb water and shrink when they dry out. Expansion is most often caused by clay materials, primarily montmorillonite and illite. Although not common, expansive rocks are also known, these are claystones or altered volcanic tuffs which contain large proportions of montmorillonite. The basic cause of expansion is the attraction and absorption of water into the expandable crystal lattices of the clay materials. The water may be derived from moisture in the air or subsurface ground water. When buildings are placed on expansive soils, foundations may rise each wet season and fall each dry season. Movements may vary under different parts of a building with the result that foundations crack, various structural portions of the building are distorted, and doors and windows are warped so that they do not function properly. The generalized distribution of expansive soils in California is shown in Figure 58.

The Southern California coastal area is of moderate to high expansiveness while the northern coastline is generally moderate.



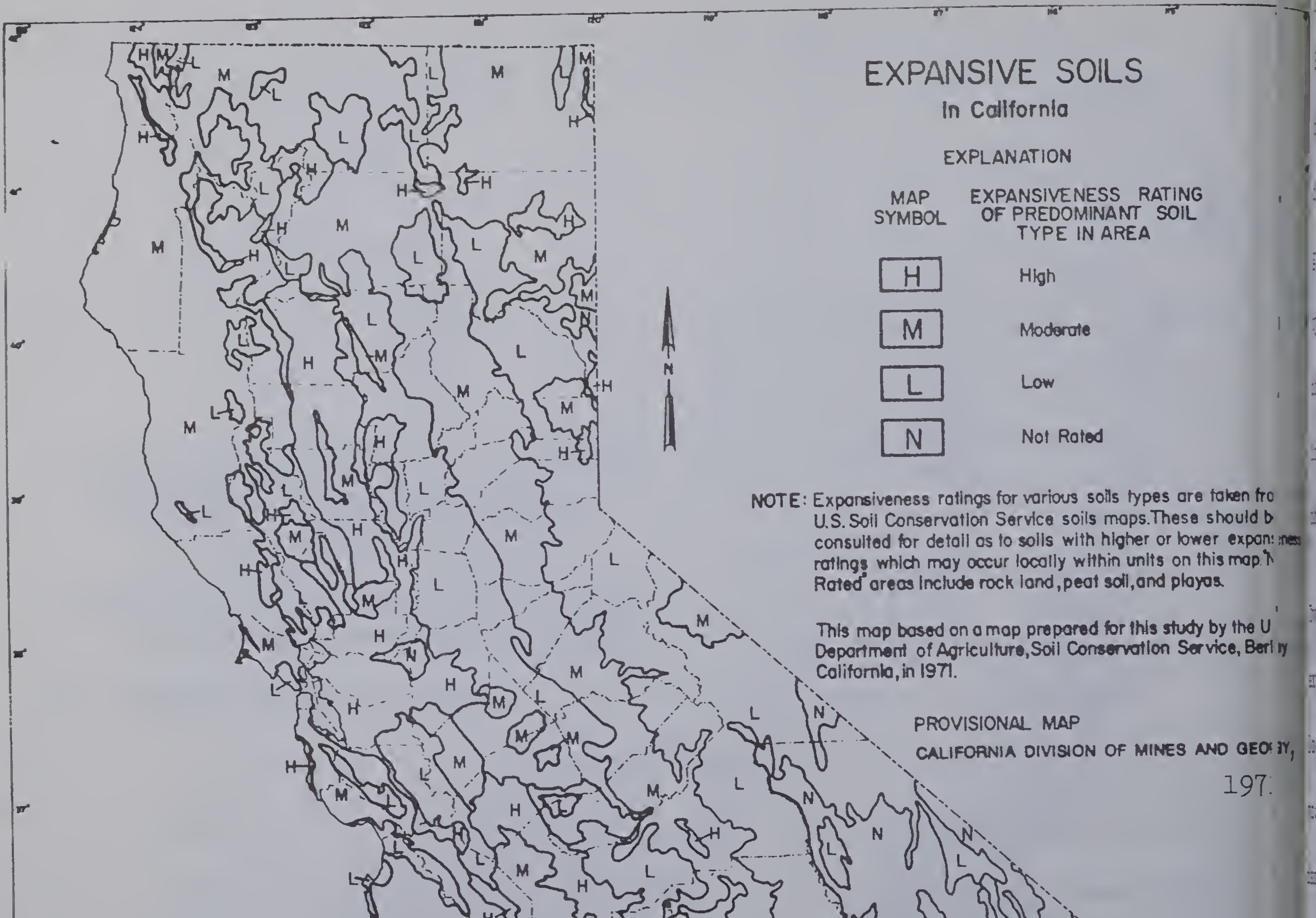
EROSION ACTIVITY
In California

NOTE: "Erosion Activity" reflects the estimated rate at which soil is being eroded naturally, from undisturbed areas. The estimated rate is based primarily on interpretation of soil survey data, including characteristics of the soil profile, slope angle, and degree of protection by vegetation.

Erosion activity data is modified after California Framework Study Committee, 1971, Comprehensive Framework Study--California Region, Appendix VIII, Watershed Management, Maps 13-22.

CALIFORNIA DIVISION OF MINES AND GEOLOGY, 1973.

Erosion activity in California.



EXPANSIVE SOILS
In California

EXPLANATION

MAP SYMBOL	EXPANSIVENESS RATING OF PREDOMINANT SOIL TYPE IN AREA
H	High
M	Moderate
L	Low
N	Not Rated

NOTE: Expansiveness ratings for various soils types are taken fro U.S. Soil Conservation Service soils maps. These should b consulted for detail as to soils with higher or lower expan ness ratings which may occur locally within units on this map. N Rated areas include rock land, peat soil, and playas.

This map based on a map prepared for this study by the U Department of Agriculture, Soil Conservation Service, Berl y California, in 1971.

PROVISIONAL MAP
CALIFORNIA DIVISION OF MINES AND GEO Y,
197

Figure 58 Expansive soils in California.

Subsidence

Subsidence of the land surface, as a result of the activities of man, has been occurring in California for many years. Subsidence can be divided, on the basis of causative mechanisms, into four types: groundwater withdrawal subsidence, oil or gas withdrawal subsidence, hydrocompaction subsidence, and peat oxidation subsidence. The distribution of the four types of subsidence in California is shown in Figure 59. Oil and gas withdrawal subsidence is the only one of the four types that will be discussed here.

Twenty-two oil and gas fields in California are known to have experienced subsidence. The better documented of these fields are located in the Los Angeles Basin where considerable damage has occurred to works of man. The most dramatic example of subsidence damage has taken place in the Wilmington field near Long Beach.

The area that subsided over the Wilmington field is intensively industrialized and initially was only 5 to 10 feet above sea level. By 1966, subsidence had placed much of the area well below sea level and extensive construction of dikes and raising of dock facilities was required. Surface deformation within the subsidence bowl had caused extensive damage to pipelines railroad tracks, and buildings.

Surface deformation, associated with oil and gas field operations in California, has manifested itself in the differential subsidence

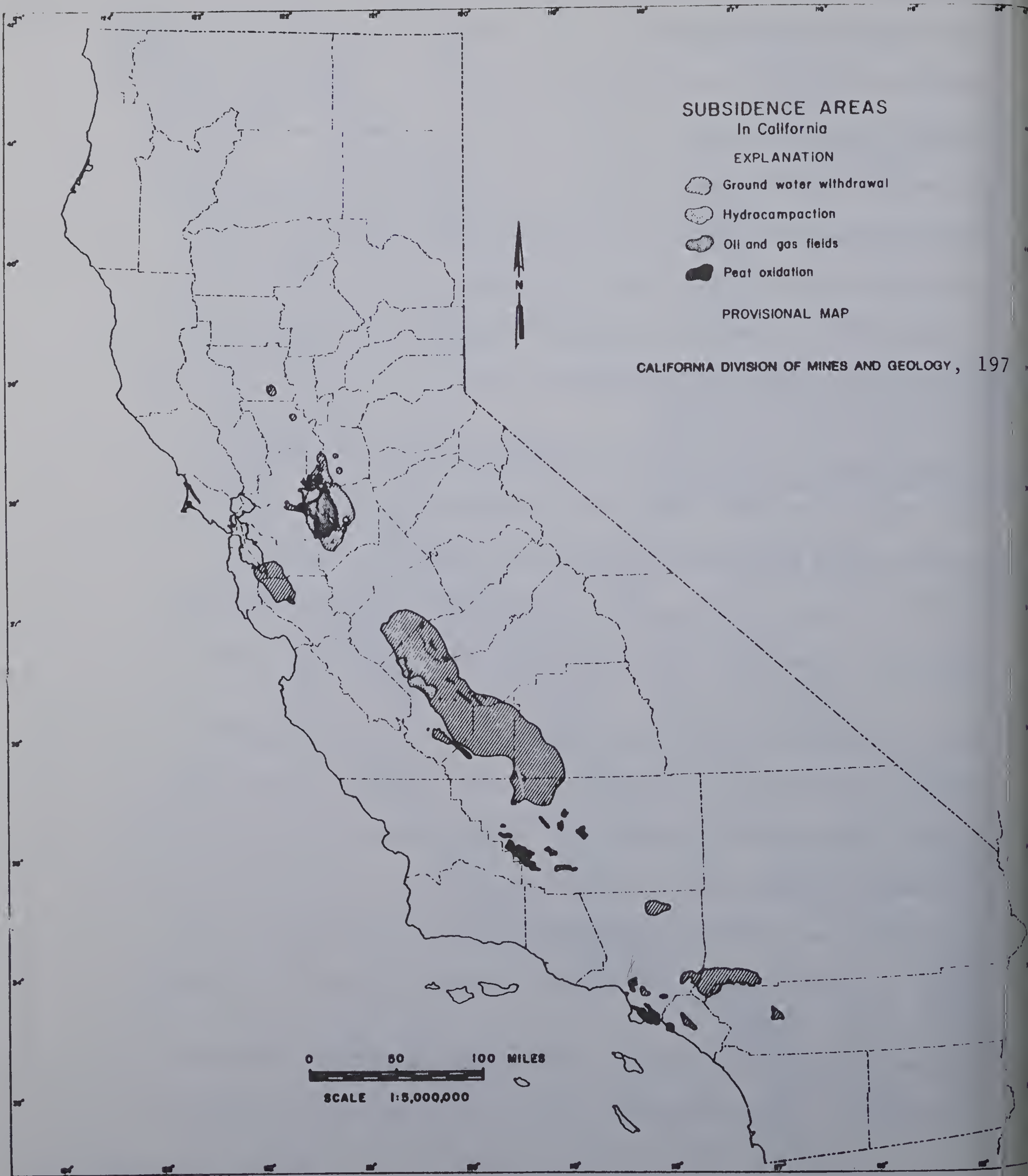


Figure 59**. Subsidence areas in California.**

of lands centering on the fields, inwardly directed horizontal displacements, and faulting. Twenty-two fields have experienced differential subsidence, three have experienced horizontal subsidence, and five have experienced faulting (Yerkes and Castle, 1969).

Differential subsidence is the most common and widespread of the surface effects. Subsidence centers over and extends well beyond the producing areas and frequently takes the shape of a bowl. Large subsidence bowls have been documented over the Wilmington field, the Huntington Beach field, the Long Beach field, and the Inglewood field.

Subsidence of the land surface, as a result of the withdrawal of oil and gas, occurs in much the same way as does subsidence from groundwater withdrawal. That is, as pore pressures are reduced in reservoirs by fluid withdrawal, the overburden load is gradually transferred to reservoir rocks and poorly consolidated claystone and shale layers below.

In the case of oil fields, magnitudes of subsidence may be comparable to those found in circumstances of groundwater withdrawal. Extensive subsidence occurred in the Wilmington oil field, where a maximum of 29 feet of subsidence was recorded to 1966; sinking was halted by repressurization in conjunction with the secondary recovery of oil.

In an area 40 miles west of Fresno, along the west side of San Joaquin Valley, a maximum of 28 feet of groundwater subsidence was recorded by 1969.

Subsidence due to gas withdrawal alone apparently does not reach magnitudes comparable to oil withdrawal subsidence.

(2) Central and Northern California

(a) General

The following discussion is abstracted primarily from Resnak (1966), Hoskins and Griffiths (1970) and text supplied by the U.S. Geological Survey.

The onshore limit of the central and northern California continental margin is defined by the western front of the California Coast Ranges, which itself is bounded to the south by the Transverse Ranges and to the north by the Klamath Mountains. Offshore the western edge of the continental margin is arbitrarily taken to be the 1,600 fm. (3,000m) contour line, which lies at the foot of the steeper continental slope where it joins the lower declivity of the continental rise. To the north and south the extensive Mendocino and Murray fracture zones are the limits. These major fractures trend from west to east towards the continents from the deep sea oceanic crust. The narrow shelf and steep slope forms a distinctive morphological entity, which is clearly different from the continental borderland south of the Transverse Ranges and different from the less steep and somewhat broader shelf and slope north of Cape Mendocino.

The significant features of the northern and central California sea floor are its very narrow shelf with a slope averaging 3°, very steep canyon-cut slope, broad continental rise containing the

Delgado and Monterey deep-sea fans, and the broad bank formed on the upper slope west of the Transverse Range. Typical profiles of the continental shelf and slope for various sections off the California coast, compared with the Sierra Nevada escarpment shown on the same scale are illustrated in Figure 60.

The major physiographic divisions of offshore central and northern California are shown in Figure 61.

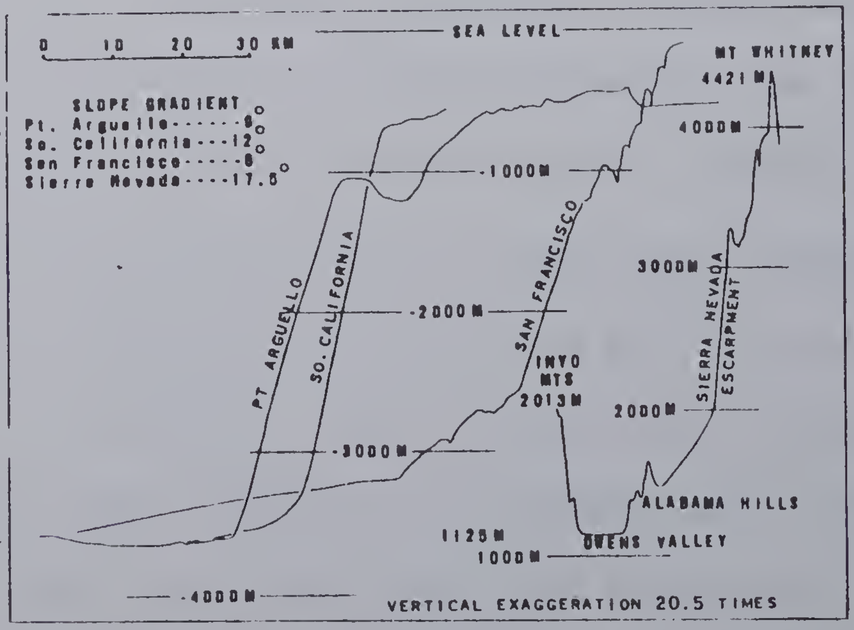


Figure 60. Comparison of three characteristic bottom profiles from the continental shelf, slope and rise of the California margin with a profile of the Sierra Nevada escarpment. (from Rusnak, 1966; after Uchupi and Emery, 1963).

The widest shelf area is found off the mouth of San Francisco Bay where the small group of Farallon Islands is developed. Width of the slope varies from 50 km. off Point Pillar to 30 km. west of Cordell Bank. This shelf area is comparable to the still broader

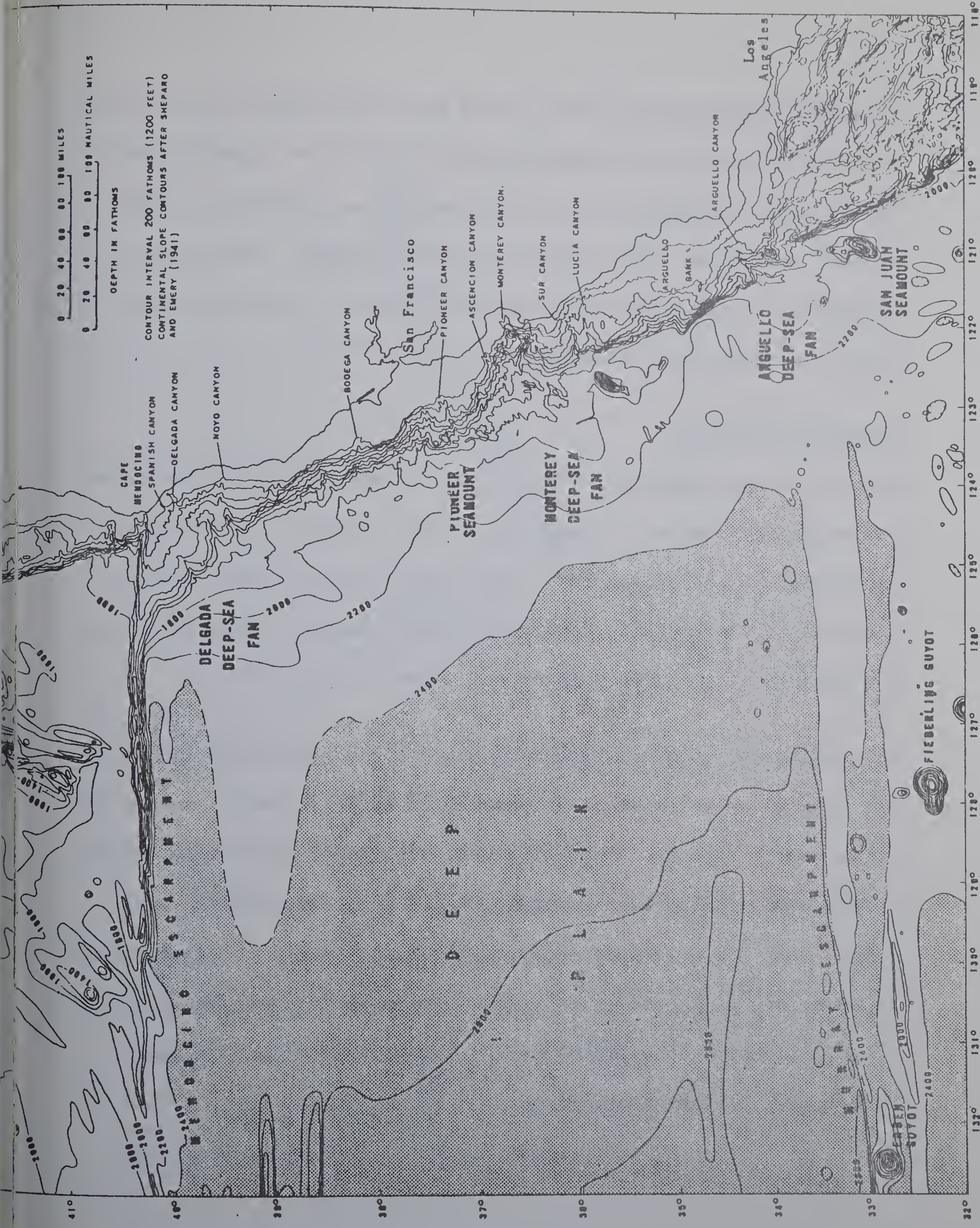


Figure 61. Principal morphologic features of the sea floor off central California (from Rusnak, 1966; after Shepard and Emery, 1941).

Arguella Plateau which forms a broad bank that should be considered not as a part of the continental shelf but rath as a gentler part of the upper continental slope with an average gradient of 6.5% through its 50 km. width (Uchupi and Emery, 1963). This area is designated as the Santa Lucia Bank and the very steep slope west of it is the Santa Lucia Escarpment.

Subsurface Geology

The continental margin of central and northern California contains six structural basins. These are of late Tertiary age and are extensions of onshore basins. From south to north these are the Santa Maria, Outer Santa Cruz, Santa Cruz, Bodega, Point Arena, and Eel River Basins. These basins are shown in Figure 62.

All six of the offshore basins of central and northern California are floored by Mesozoic age basements of either igneous, metamorphic or sedimentary rocks. The Eel River, Santa Cruz, and Santa Maria Basins have sandstone of a marine origin at their bottoms. The Point Arena Basin is floored by metasediments while the Bodega Basin is underlain by granodiorite. Total sediment thicknesses vary from a low of greater than 10,000 feet in Santa Maria Basin to over 20,000 feet in Santa Cruz Basin.

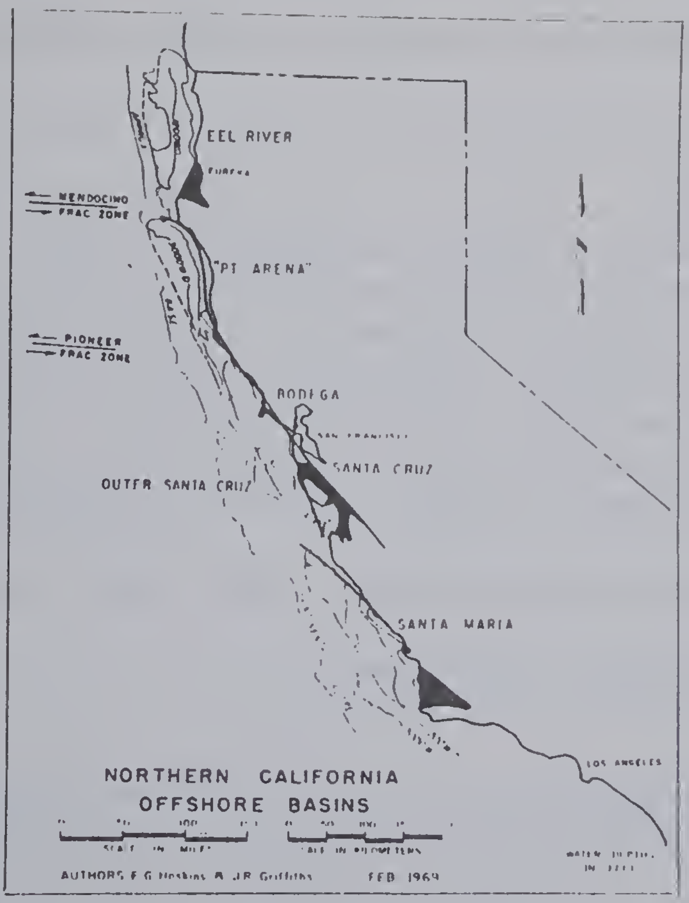


Figure 62. Location of structural basins offshore central and northern California (from Hoskins and Griffiths, 1971).

Total section thicknesses are as follows:

Santa Maria Basin	10,000 feet+
Santa Cruz Basin	20,000 feet+
Outer Santa Cruz Basin	12,800 feet+
Bodega Basin	13,500 feet+
Point Arena Basin	10,900 feet+
Eel River Basin	16,400 feet+

Tertiary sections greater than 10,000 feet are found in all basins. The Miocene section is the thickest of the tertiary units.

Santa Maria Basin

The Santa Maria basin offshore extends from Point Arguello northwest to Point Sur just south of Monterey. It is a shallow post-middle Miocene synclinorium about 140 miles (225 km) long and averaging 25-30 miles (40-48 km) in width. This 3,500 square mile (9,065 sq km) area contains approximately 1,800 cubic miles (7,500 cu km) of Miocene and younger marine beds.

Figure 63 shows two sections across the Santa Maria Basin.

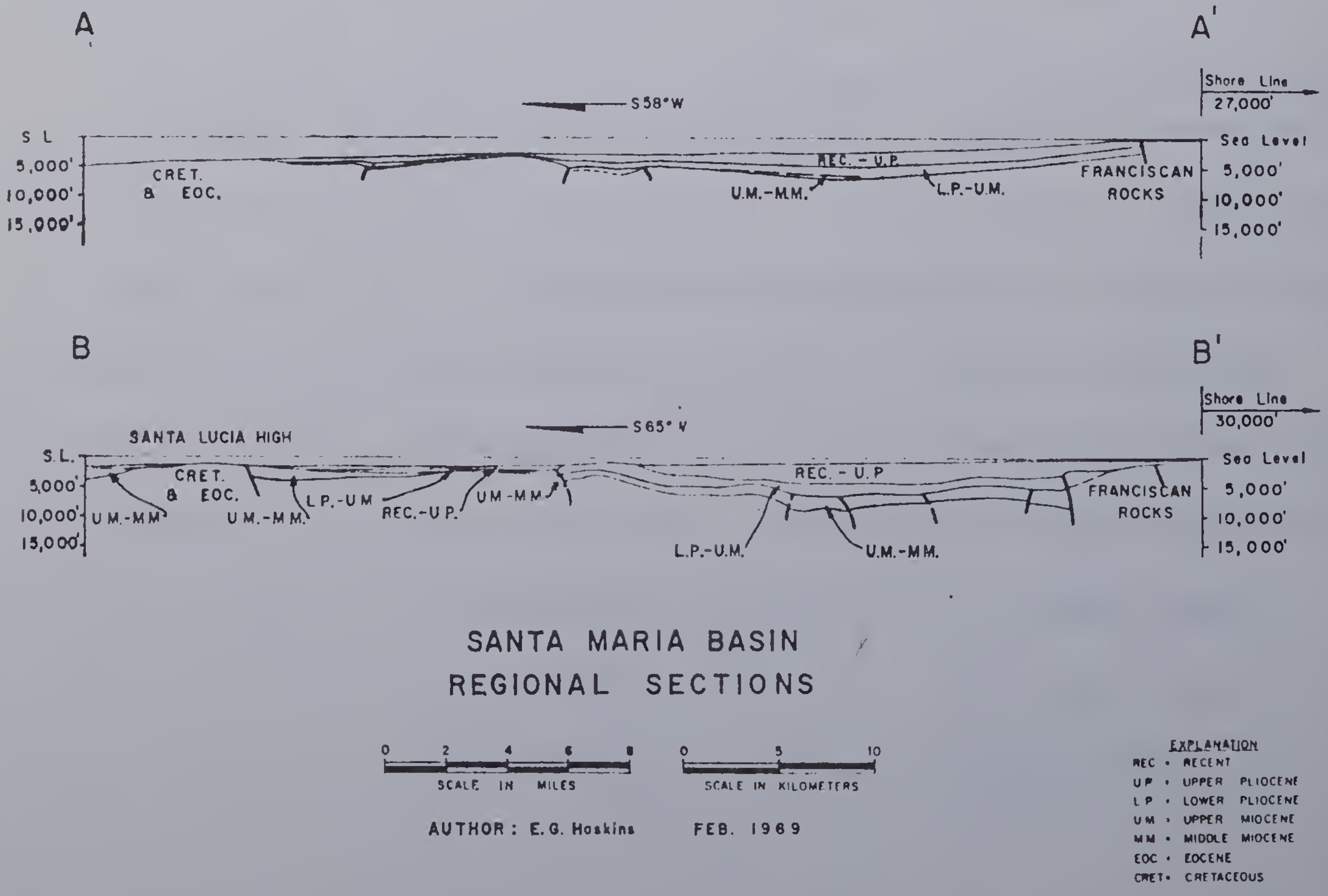


Figure 63 Structural Sections Across the Santa Maria Basin. Section A-A'is from Ragged Point to the slope while B-B' is from Grover City to the Santa Lucia High. (from Hoskins and Griffiths, 1971).

Outer Santa Cruz Basin

The Outer Santa Cruz Basin extends northwest from Monterey for 80 miles (130 km) to about 37° 30' N latitude, where it appears to merge with the continental slope. It is a shallow, post-middle Miocene syncline which encompasses approximately 1,400 square miles (3,630) and contains about 1,400 cubic miles (5,830 cu km) of Miocene and young marine beds. A cross section of the Basin is shown in Figure 64.

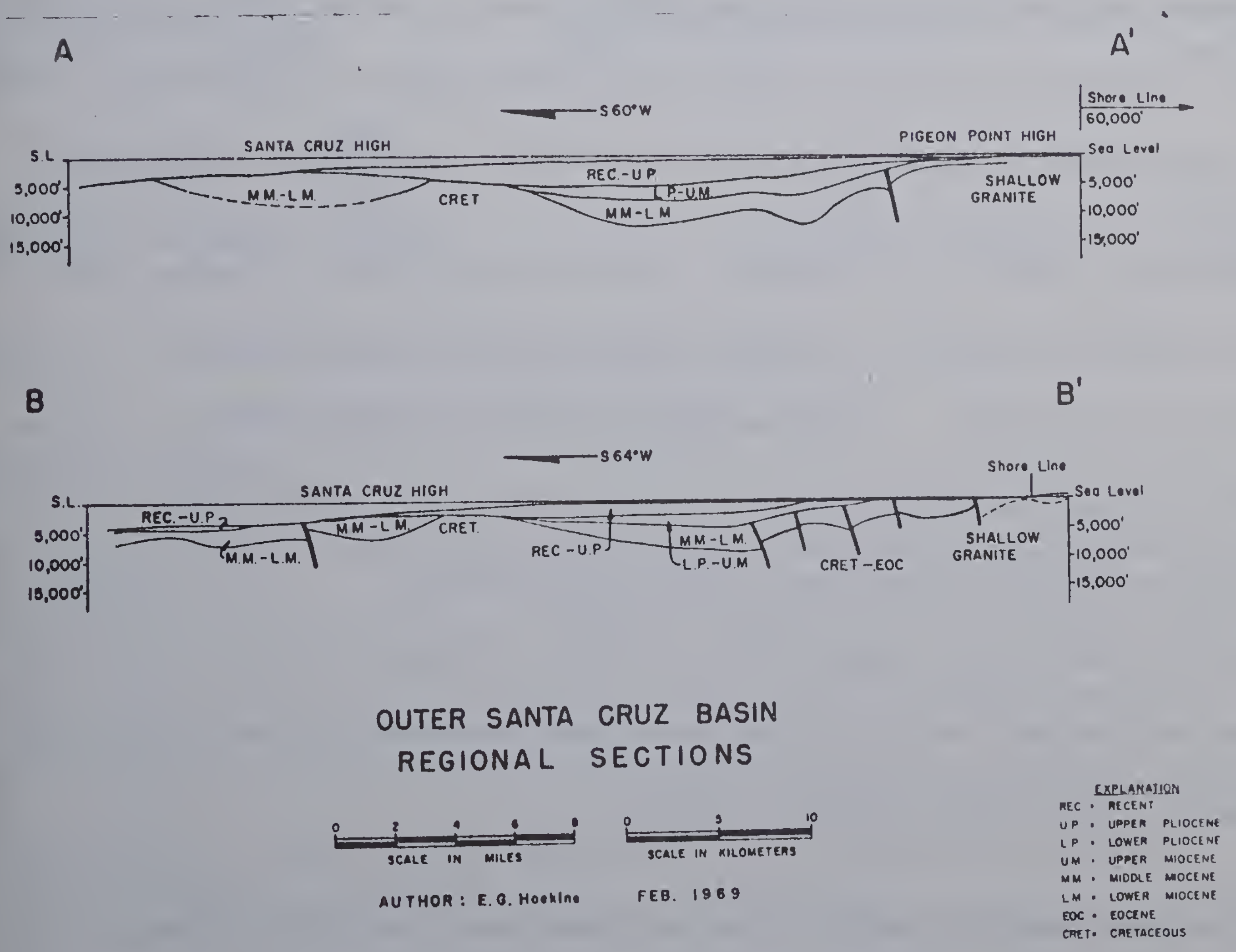


Figure 64. (from Hoskins and Griffiths, 1971).

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The Santa Cruz Basin and the Bodega Basin

The Sant Cruz Basin and the Bodega Basin are contiguous. The Santa Cruz basin which is bounded on the southwest by the Pigeon Point high and restricted on the northeast by the Montara Granite and the San Andreas fault, encompasses approximately 300 square miles (780 sq km) and contains about 450 cubic miles (1,875 cu km) of Eocene and younger marine strata. It is considered to be the seaward extension of the Purisima trough.

Basement in the basin is probably Cretaceous granite, which is known to be present on the north, east, and south sides. Sedimentary rocks of approximately equivalent age are present as erosional remnants.

The Bedega basin is an elongate, shallow late middle Miocene synclinorium which extends offshore from San Francisco to about 38° 45' N latitude. It encompasses an area of about 85 by 17 miles (137 x 27 km) and contains on the order of 1,600 cubic miles (6,670 cu km) of Miocene and young marine strata. A thick section of marine shale and sandstone is present. Large, closed anticlines have been mapped and oil shows have been recorded; water depths are generally less than 600 feet (180 m).

Cretaceous granite, which crops out onshore from Point Reyes to Bodega Head and offshore on the Farallon Islands high, is present beneath the Basin and imparts a rigid, block-faulted structural style. There is a basinwide angular unconformity between the Eocene and Miocene; local unconformities are present between the lower and middle Miocene and within the lower upper Miocene. Structural cross-sections of the two basins are shown in Figure 65.

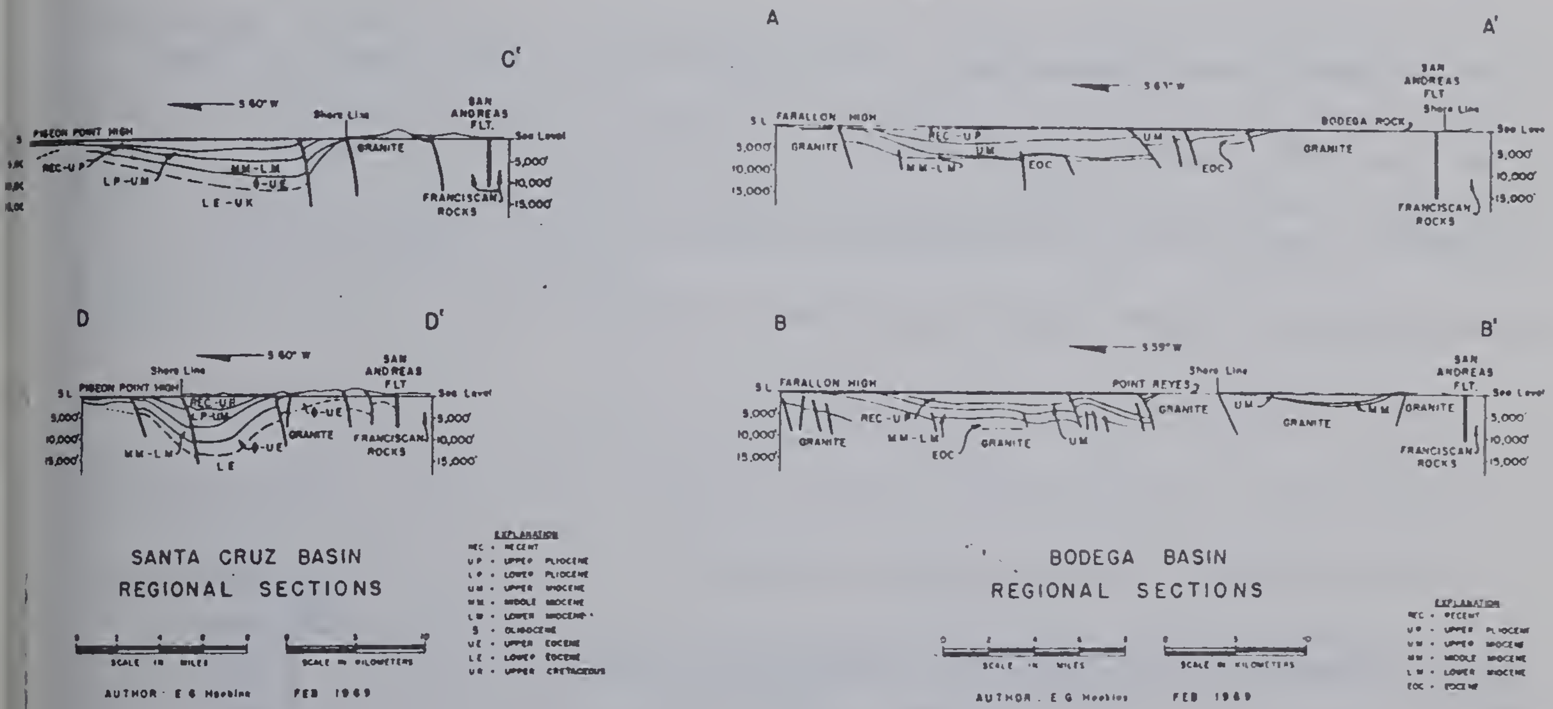

Figure 65. The Santa Cruz and Bodega Basins.
(from Hoskins and Griffiths, 1971).

Point Arena "Basin"

Point Arena "Basin" does not have a continuous western margin uplift and thus does not constitute a basin of deposition in the same sense as the other five basins discussed. This area is a poorly defined tract bounded on the east by the San Andreas fault, on the west by the approximate upper edge of the continental slope, on the north by the Mendocino fracture zone, and on the south by Point Arena. These boundaries encompass an area of approximately 3,000 square miles (7,770 sq km) which contains on the order of 3,000 cubic miles (12,500 cu km) of Miocene and younger marine sedimentary rocks.

This area is moderately complex structurally and has several large, untested structures. Oil shows are common in the upper and middle Miocene, and several oil or tar sands crop out onshore at Point Arena.

Pre-Cretaceous metasedimentary rocks underlie at least part of the area, and the southern half shows a structural style markedly different from that of the adjacent granite-floored Bodega Basin. Cross-sections of the basin are shown in Figure 66.

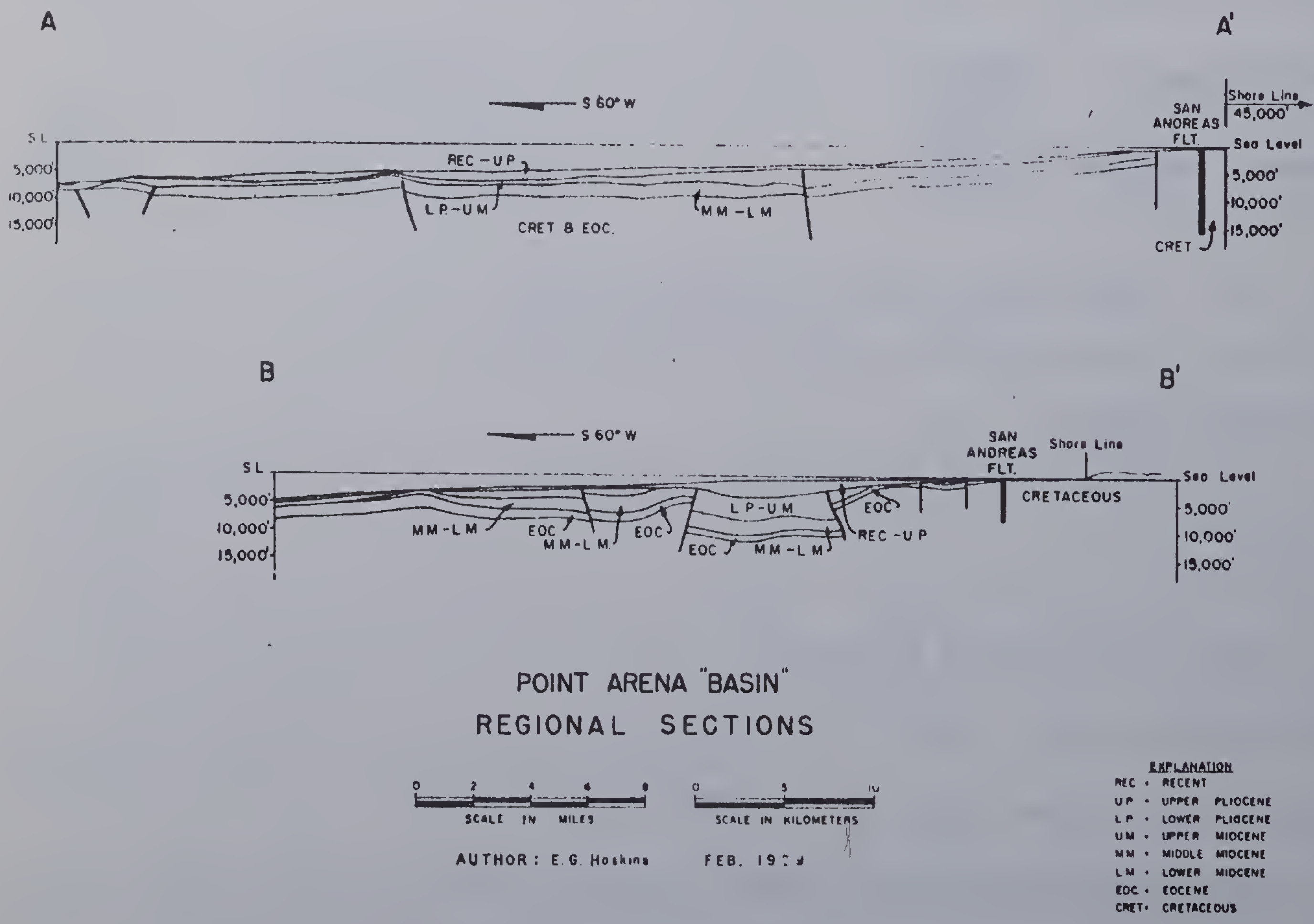

Figure 66. (from Hoskins and Griffiths, 1971).

Eel River Basin

Of the six basins described, the Eel River is the largest in areal extent and possibly in volume of marine strata. It extends from False Cape, south of Eureka, north into Oregon to about Cape Sebastian, a length of approximately 130 miles (210 km). The basinal outline enclosed an area of 4,000 square miles (10,360 sq km), which contains an estimated 7,000 cubic miles (29,170 cu km) of marine Miocene and younger strata.

The main structural features in the basin are nearly parallel with its long axis, which has a west-northwest trend onshore and swings to a north trend offshore. Folds onshore, including the productive Table Bluff and Tompkins Hill anticlines, appear to be at least partly due to compressional buckling associated with the uplift of the present basin margins. Several folds and faults offshore display an en echelon relation which suggests horizontal shear forces. Structural sections of the Eel River Basin are shown in Figure 67.

Oil and Gas Seeps

Oil and gas seeps occur both offshore and onshore. Offshore seeps are restricted to the area from Point Conception in Santa Barbara County to Huntington Beach in Orange County. The California Division of Oil and Gas (1973) has identified 54 major seep areas. Many more probably exist.

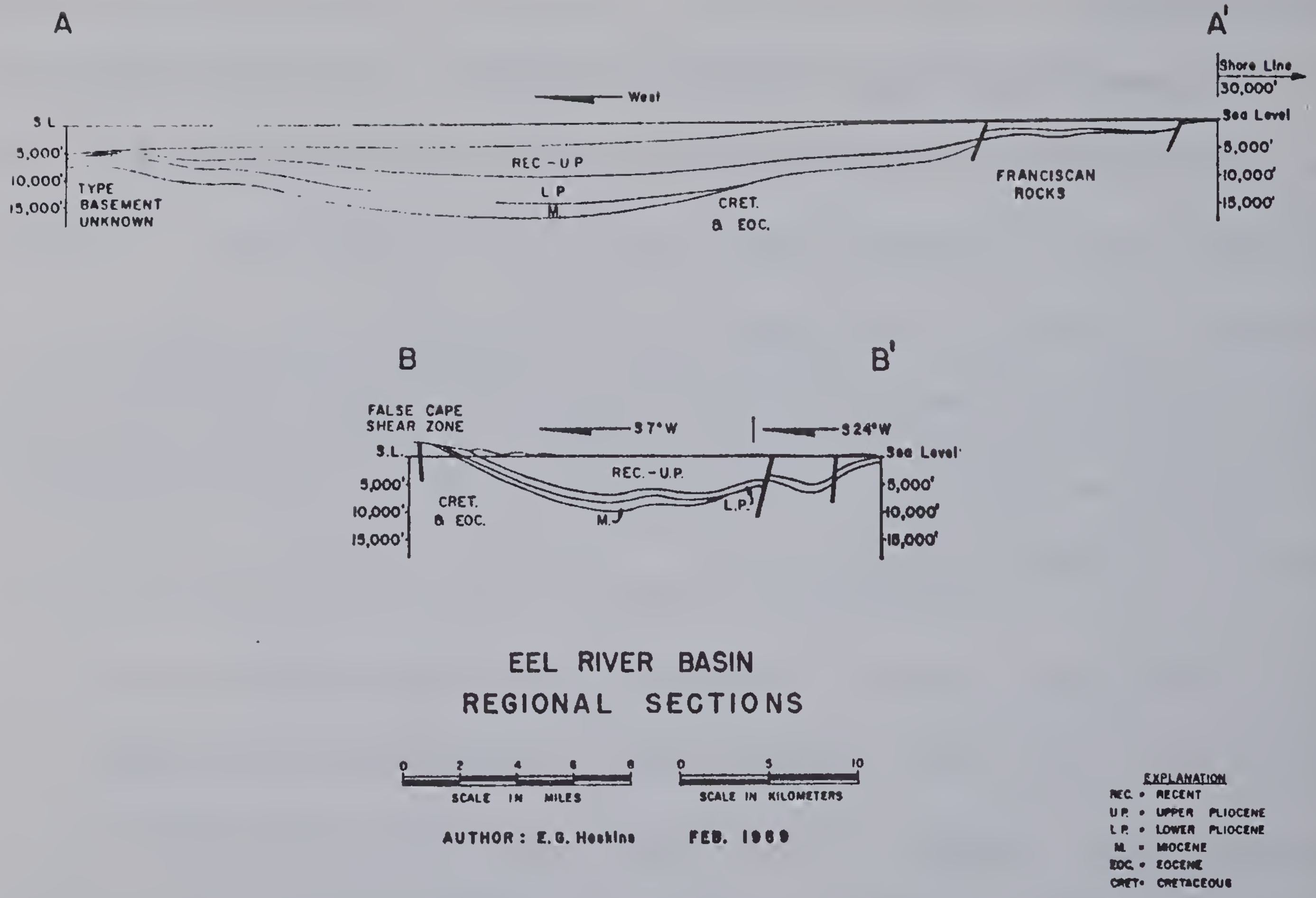

Figure 67. (from Hoskins and Griffiths, 1971).

Numerous onshore oil producing basins have natural seeps. These include the Bear-Mattole and Elk River Basins in Humboldt County, the Ventura Basin in Ventura County and the Los Angeles Basin in Los Angeles County.

(b) Hydrocarbon Potential

Eel River Basin contains numerous large structural traps and a potentially thick marine shale section. Indications of local shale flowage and diapirism are also present. Miocene marine clastic strata extend offshore and probably contain reservoir-quality sandstone. Pre-Miocene strata appear to have poor petroleum potential. Onshore production has yielded 56 BCF of gas from thin, lenticular and very fine-grained Pliocene sands, along with minor quantities of oil from the Mesozoic. Equating onshore gas production to oil at 5.6 MCF/bbl., gives an equivalent value of 10 million bbl. of oil. Total discovered onshore reserves are estimated at 80 BCF or 14 million bbl. of equivalent oil.

Only limited hydrocarbon shows have been found offshore, however, the Eel River Basin is largely untested and appears to have good hydrocarbon potential, particularly for gas. Economically attractive offshore strata however, lie mainly beneath the western two-thirds of the basin where water depths exceed 460 meters.

Hydrocarbon shows onshore Bodega and Santa Cruz Basins have not been significant. The more promising potential reservoir strata and structural traps have already been tested and results suggest that these sections have low hydrocarbon potential.

The offshore Santa Maria Basin seems to represent an excellent continuation of onshore stratigraphic, lithologic and structural trends. Onshore production has been primarily from fractured Miocene shales and, to a lesser extent, fine-grained lenticular Pliocene sands. Cumulative petroleum production (to 1-73) of 609 million bbl. had been achieved by dense exploratory drilling, close spacing of wells in known fields and expensive well treatments, due to the low gravity (high density) nature of the crude.

Potential reservoir strata are limited in the southeastern one-third of the basin while most of the remaining area is characterized by a thin, poorly-known Tertiary section and water depths commonly exceeding 450 meters.

(c) Geologic Hazards

A general discussion of potential geologic hazards offshore California is included in section II.A.3.a.(1)(c), pp.

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(3) Washington-Oregon Pacific OCS

(a) General

The continental margin off Oregon and Washington represents the western part of a Tertiary depositional trough that trended north-south from what is now Vancouver to the Klamath Mountains. Width of the trough extended from the Cascade Mountains to near the base of the present continental slope. Two prominant subsea features, the Cobb and Blanco Fracture Zones represent approximate natural offshore boundaries on the north and south, respectively (Fig. 68).

Oldest rocks in the depositional basin are early Eocene volcanics which form the effective basement, or subsurface boundary upon which potential oil and gas strata may lie. The entire Tertiary basin sequence is thought to overlie oceanic crust although late Cretaceous deposits exposed along the southern margin may be present within the trough as well. Within the basin, the middle to late Tertiary section generally consists of a marine sandstone and siltstone sequence up to 25,000 feet thick, with occasional interbedded volcanic and non-marine rocks. Drilling offshore central Oregon has penetrated over 12,000 feet of rock dating from late Eocene to recent (Figure 69). In view of the limited well data and thick overburden of Holocene sediments, estimates on the nature and distribution of the Tertiary strata offshore Washington are largely speculative.

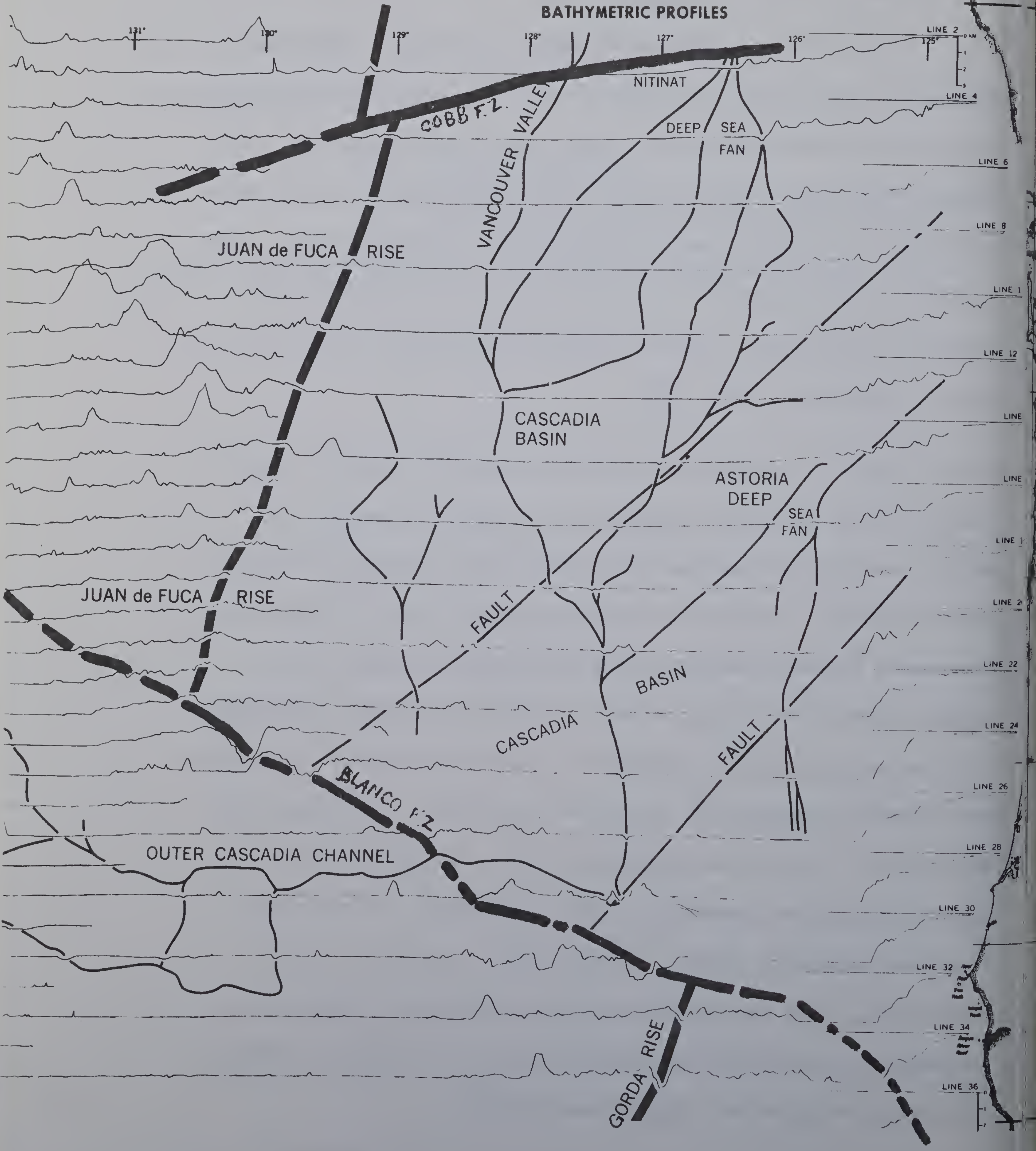


Fig 68. Geomorphic Features of the offshore Oregon and Washingtor area.

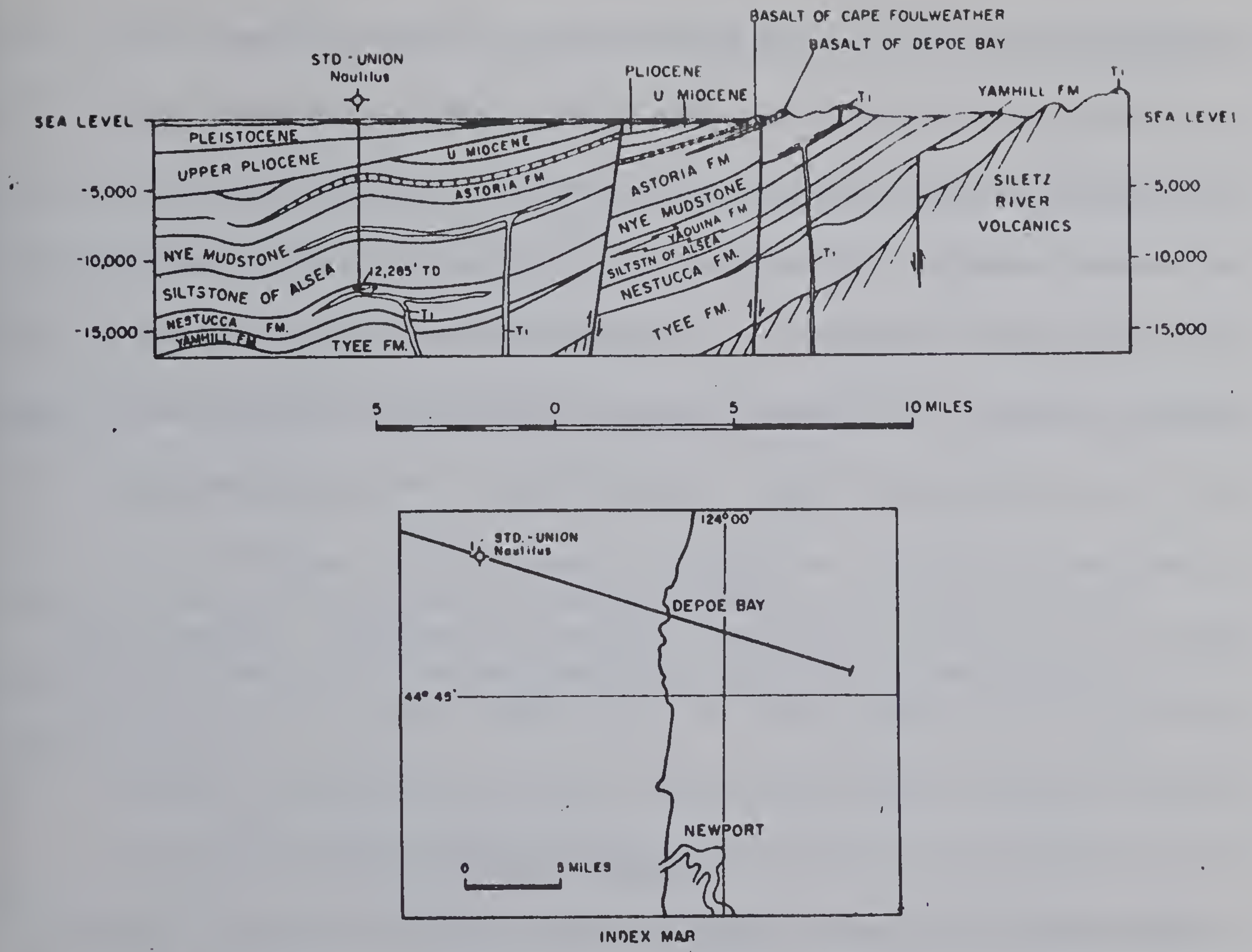


Fig.69 a. -Cross section from central Coast Range to continental shelf of Oregon near lat. 44°45'N.

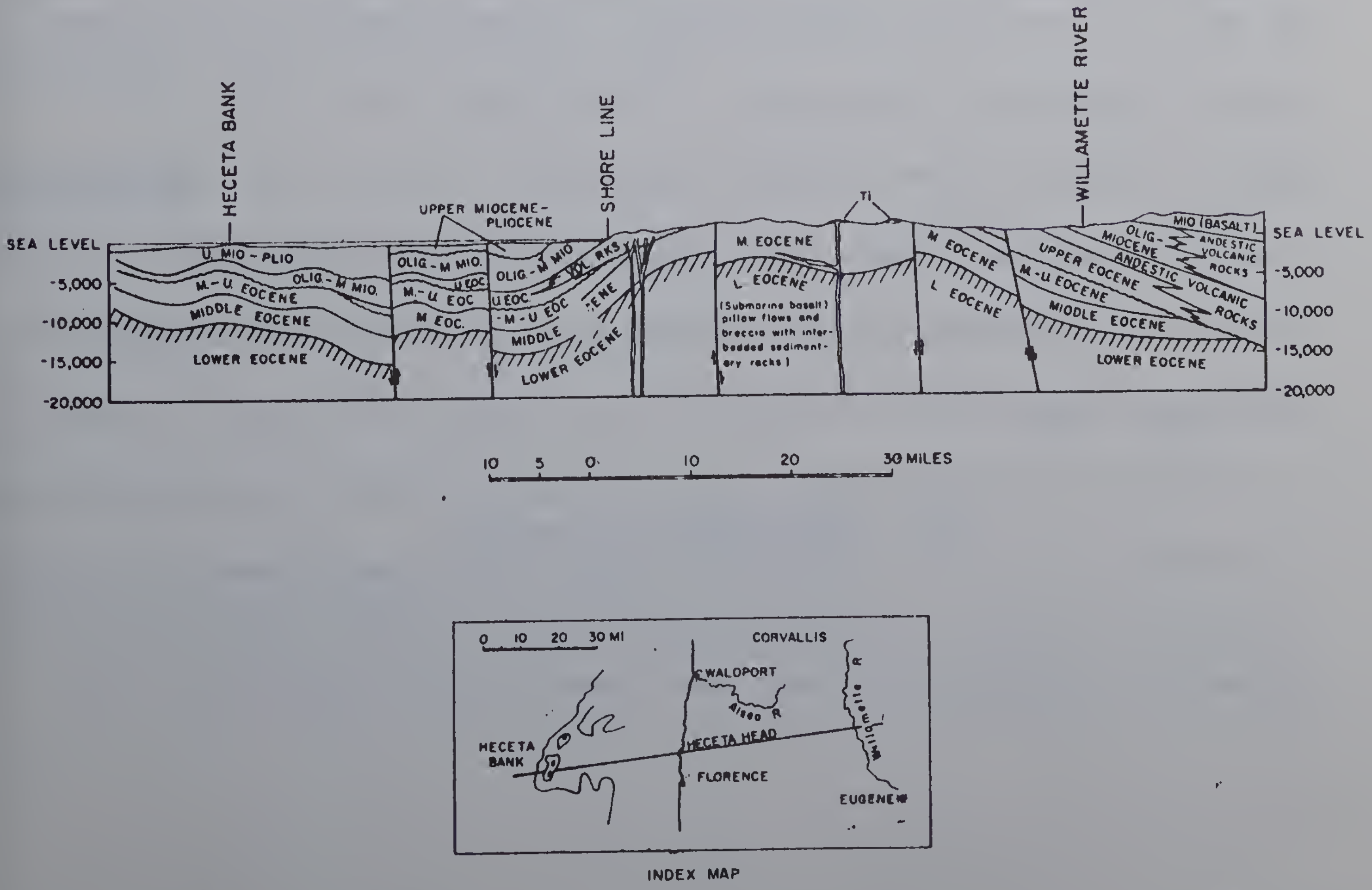


Fig. 69 b.-Diagrammatic cross section from Willamette Valley to continental shelf of Oregon near lat. 44°N.

(from Braislin, et al., 1971).

The depositional history of this structural province has been complicated by periodic submarine, subaerial and deep-seated volcanism accompanied by several phases of tectonic uplift and subsequent erosion. The latest period of major crustal uplift, which occurred during the late Tertiary and early Quaternary periods, elevated the thick Tertiary sedimentary section into what is now the Coast Range. Structurally, the Coast Range is a broad anticlinorium, or regional upwarp, that consists of numerous alternating structural ridges and troughs. These folds continue offshore where some of the ridges appear to be actively growing, involve Quaternary strata and form bathymetric highs. The late Tertiary strata are cut by numerous shale diapirs on the Washington and western half of the Oregon continental margin.

Oil and Gas Seeps

Oil and gas seeps have been reported from the coastal area of the Olympic Peninsula of Washington. These seeps along with petroliferous rich muds known as the "smell muds" are the only reports of natural seepage found. The smell muds are found in the vicinity of the mouth of the Hoh River as well as further north along the coast.

(b) Hydrocarbon Potential

Although hydrocarbon production onshore Oregon and Washington has not been commercially significant, the thicker late Tertiary sequence found offshore may hold more promise. Mid to late Tertiary sandstone strata which outcrop onshore are probable well represented beneath the continental shelf. Limited offshore drilling and seismic data have revealed diapiric shale offshore Washington and northern Oregon. In general, these data suggest that structural and stratigraphic trapping potential is good in the areas surveyed.

A realistic appraisal of hydrocarbon potential in this OCS area, however, must await the accumulation of additional geophysical and test drill data.

(c) Geologic Hazards

Data about geologic hazards in Oregon and Washington is very limited. However, a survey of existing literature revealed material concerning earthquakes, mass wasting and floods. These are discussed below.

Earthquakes

Both Washington and Oregon have histories of earthquake occurrence. In Washington, the majority of quakes were centered in the vicinity of Seattle, Tacoma and Olympic where numerous earthquakes, some with intensities as high as VIII on the Mercalli Scale have been reported. Coastal Washington has experienced very few earthquakes with only a handful from Clallam and Grays Harbor Counties recorded.

Oregon is very similar to Washington in having a history of earthquakes but no major destruction. All of Oregon's coastal counties have reported earthquakes. Couch and Lowell (1971) compute that the Coast Range of Oregon will have one 5.0 magnitude earthquake each decade. Lincoln County has had seven quakes during a seventy-year period ending in 1967. Four of these were centered at Newport (maximum intensity IV). (See Figures 70 and 71).

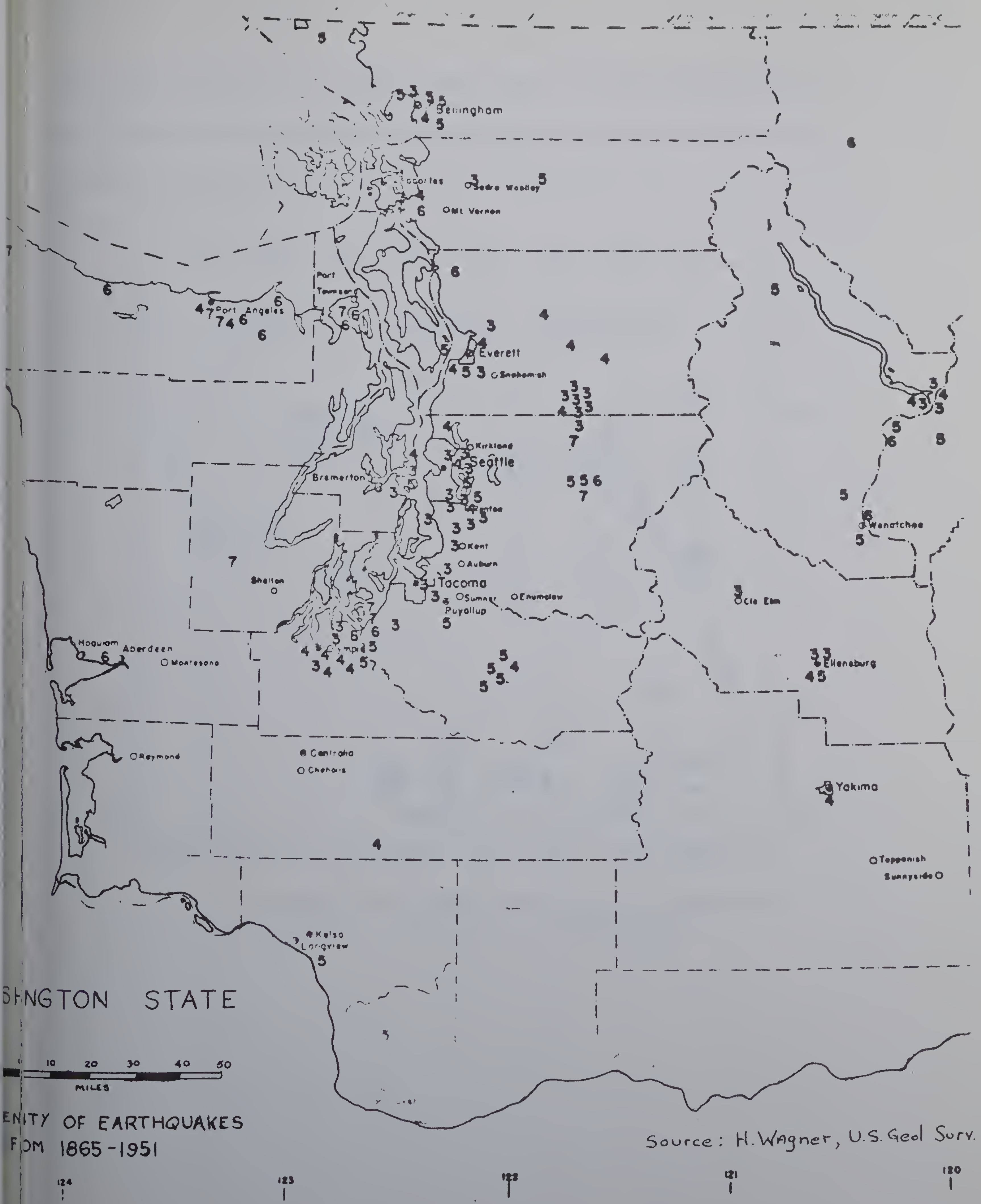
Mass Wasting

Both the Oregon and Washington coastlines have areas subject to landsliding and slumping.

In Oregon coastal outcrops of the Nestucca, Astoria and Nye formations as well as bedded volcanic rocks are frequently the locale for slumps and slides. Most of these occur as slides along bedding planes which dip towards the sea (Oregon Dept. of Geology and Mineral Industries, 1973). Washington's coastal area also is the location of units which dip towards the sea. Many active slides and slumps are known from the Hoh Rock Assemblage of the central Washington coastal area.

Flooding

The coastal ranges of Oregon and Washington are centers of high precipitation. Rainfall of up to 100 inches per year causes widespread spring and fall flooding. The Columbia, Siletz, Umpqua and many other rivers have flooded during historic time.



SHNGTON STATE

ENITY OF EARTHQUAKES
FOM 1865-1951

Source: H. Wagner, U.S. Geol Surv.

Figure 70 .

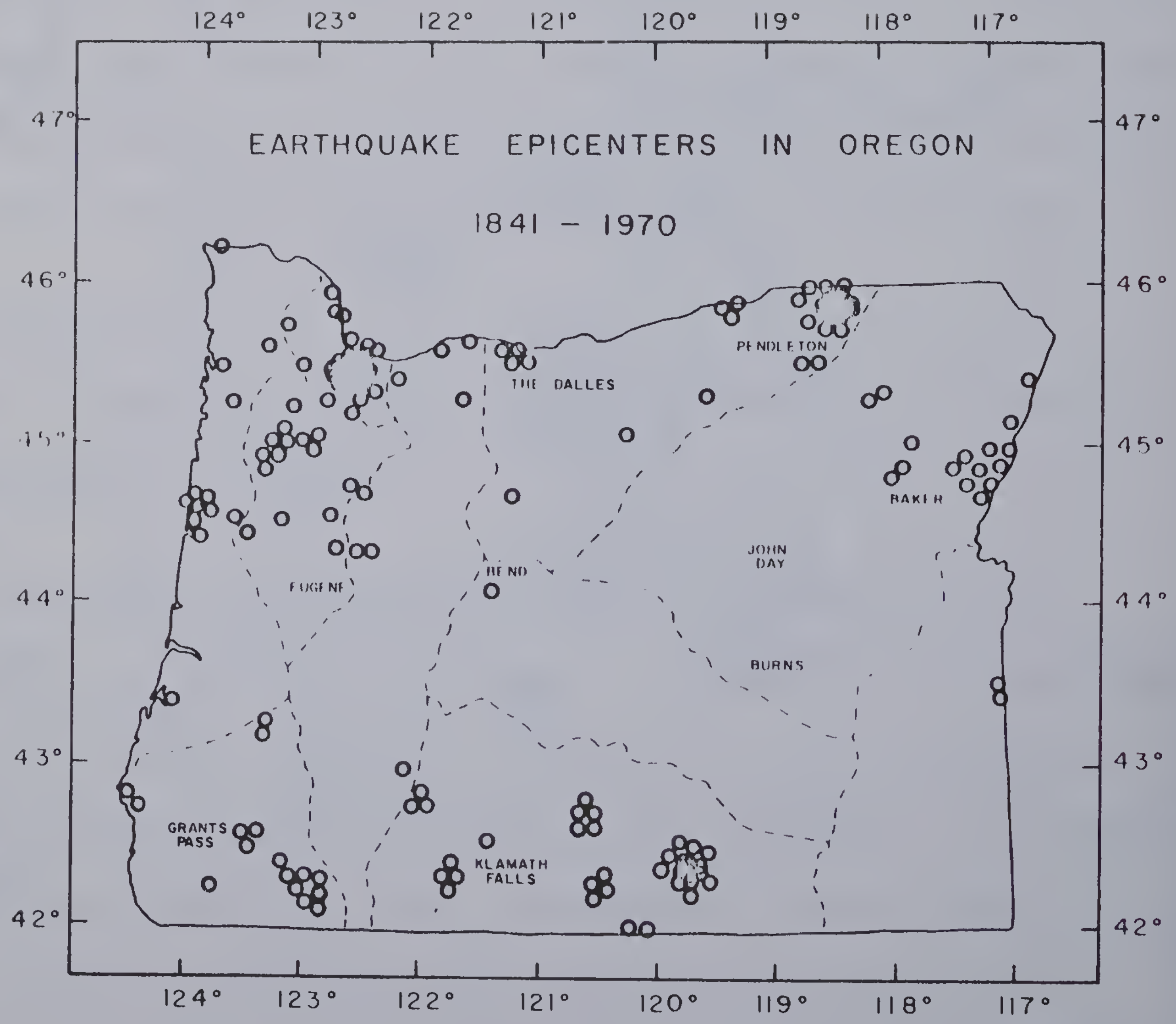


Figure 71. Earthquake epicenters in Oregon: 1841 through 1970. (from The Ore Bin, 1971).

The 1894 flood of the Columbia River had a maximum discharge of over 1.2 million c.f.s. Lowland flooding produces many mudflows along areas with gradients.

b. Climate

(1) General Climatology and Seasonal Weather Patterns

The climatology of the Pacific Coast is influenced chiefly by the location and intensity of the Pacific high and Aleutian low pressure systems. The former system, located off southern California around 140° to 150° W. longitude, is a fairly stable system throughout the year. The Aleutian low is a much more transient system with variable intensity. The gradient between these two systems determines the direction and strength of winds and weather systems off the Pacific coast.

During the summer months, the Aleutian low is almost non-existent, resulting in no gradient between the two oceanic systems. However, a gradient does form between the oceanic system and a continental low pressure center. Consequently, moderate winds, predominantly from the north and northwest occur along the entire Pacific coast. For the most part, these winds bring cool moist air onshore, often forming fog along the coast.

In the fall the Aleutian low begins developing over the Gulf of Alaska and Bering Sea. Winds increase in velocity and blow from the southwest and west. Along the coast from northern California to British Columbia, low pressure storm systems pulse onshore from the west almost continuously throughout the winter, bringing rain and cool temperatures. Along the southern California coast the storms are shunted to the north by the high pressure system offshore. Winds are light, rain showers are few, and days are generally sunny and relatively warm.

The Aleutian low gradually weakens during the spring. Storms become less frequent and pass farther north over the continent. As summer progresses, daily atmospheric pressure fluctuations become much smaller in magnitude and the winds begin shifting to the north and northwest.

(2) Sky Cover and Visibility

Two meteorological phenomena, clouds and fog, are responsible for variations of sky cover and visibility. The distinction between clouds (associated with storm fronts) and fog (associated with near-surface local effects) is often neglected because of their similarity. The distinction is important for offshore operations where fog is less frequent than in coastal areas.

In general, cloud cover increases in the northern latitudes, both in areal extent and duration. Cloud cover is about 10 to 20% greater off northern California. Mean annual sky cover, on a scale from 0.0 to 1.0, ranges from 0.4-0.6 in California, to 0.6-0.8 off Oregon and Washington (U.S. Dept. of Commerce, 1968). April, May and June are the least cloudy months along the Pacific coast States.

Fog is common along the Pacific coast and can be very frequent and extensive in the summer. This is the result of warm moist air from offshore moving over the cold upwelled water along the coast. As the relative humidity equals and exceeds 100%, fog forms and drifts inland. The seaward extent of fog is variable, depending on the extent of cold coastal water and numerous other conditions. Fog can range from a few hundred yards to hundreds of miles offshore (U.S. Dept. of Commerce, 1968).

Reduced visibility is a result of a combination of cloudiness and fog. Although heavy fog and cloudy conditions frequently occur, extreme reduction of visibility is not particularly common nor long-lasting. The frequency of days with less than one-mile visibility does not exceed 5 to 10% during the year along the entire coast. During the summer months the frequency of days with less than five-mile visibility approaches 25% at times along the central Pacific coast (U.S. Dept. of Commerce, 1961).

(3) Surface Wind Patterns

Wind patterns along the Pacific coast are the result of atmospheric pressure systems discussed in the climatological section above. Summer winds blow from the north and northwest with average velocities ranging from 6 to 14 knots, depending on the month and year. Winter winds blow from the south and southwest with average velocities of 6 to 10 knots (U.S. Dept. of Commerce, 1961).

Average wind velocities are somewhat misleading, particularly during the winter months, when gales (34 knots) are frequent along the northern portion of the Pacific coast. Summer gales occur but with considerably less frequency.

Winter gales accompany about 5 to 8% of the storms crossing the northern Pacific coast, while only 1% of the storms off southern California are accompanied by gales. These winds are invariably from the south. Along the southern California coast (south of 35°N.), gales are very infrequent, with no predominating direction (U.S. Dept. of Commerce, 1963).

Superimposed on the basic north-south blow of winds are the local onshore-offshore sea breezes. These diurnal (occurring daily) winds develop from unequal heating and cooling of the ocean and adjacent land mass. As the land is heated, the air above rises, creating an area of low pressure. This induces the cooler air over the ocean to flow onshore throughout the day. At night, thermal conditions are reversed, resulting in weak offshore breezes in the early morning.

Velocities of sea breezes are generally in the range of 15 to 20 knots (Allan Hancock Found., 1963). These winds in themselves do not constitute a hazard, but may intensify a major storm system in the area. Depending on the location, season, and weather conditions, the effect of the sea breeze may extend far offshore.

(4) Air Temperature

Air temperatures along the Pacific coast are controlled by the marine environment. The ocean, with its high specific heat (the amount of heat required to raise the temperature of water 1°C.), acts as a heat reservoir to damp out daily and seasonal oscillations of temperature. Days are cool and nights are relatively warm. Air temperature variations occur slowly, and extreme variations are seldom experienced.

Mean temperatures recorded at various coastal areas are useful for illustrating the differences along the coast. The U.S. Dept. of Commerce (1968) gave several thermal descriptions for Pacific coastal locations as shown in Table 21.

Offshore air temperatures are generally warmer than the adjacent coastal temperatures. Mean maximum temperatures in the summer off southern California are about 10° higher offshore, and about 15° higher during the winter (SCOSC, 1974). Similar differences occur in more northern waters. Although this suggests that freezing air temperatures never occur offshore, polar air masses from the continent may move short distances offshore at times during the winter.

(5) Precipitation

Precipitation along the entire Pacific coast occurs predominantly from late fall through early spring. The

TABLE 21.

TEMPERATURE RANGES (°F) FOR FOUR PACIFIC COAST CITIES

	Los Angeles	San Francisco	Eureka (Calif.)	Astoria (Oregon)
Highest temperature	90	79	77	65
Normal Maximum	64	55	54	47
Normal Average	54	49	47	41
Normal Minimum	45	42	41	35
Lowest Temperature	28	29	20	14

amount of yearly rainfall increases as one moves from south to north (Fig. 72). The Washington coast receives nearly five times as much precipitation annually as the southern California coast. This large difference between regions illustrates the influence of the Pacific high pressure system which causes winter storms to be deflected onto the Oregon and Washington coasts.

Elliot and Reed (1973) showed that precipitation offshore was only about one-half to one-third of that found at coastal land stations along the north Pacific coast. These results indicate offshore rainfall may also be considerably less than precipitation measured at California coastal weather stations.

(6) Storms

Storms which occur along the Pacific coast are almost invaribly associated with the movements and changes in intensity of the Pacific high pressure system. As the system weakens or moves to the south, low pressure systems from various locations move closer to the Pacific coastal States bringing winds and sometimes rain with them. There are three primary geographical locations which generate storms which affect the Pacific coastal areas (Allan Hancock Found., 1963). These are: 1) the southern Gulf of Alaska, 2) northern boundary of the Pacific high, and 3) tropical hurricane latitudes.

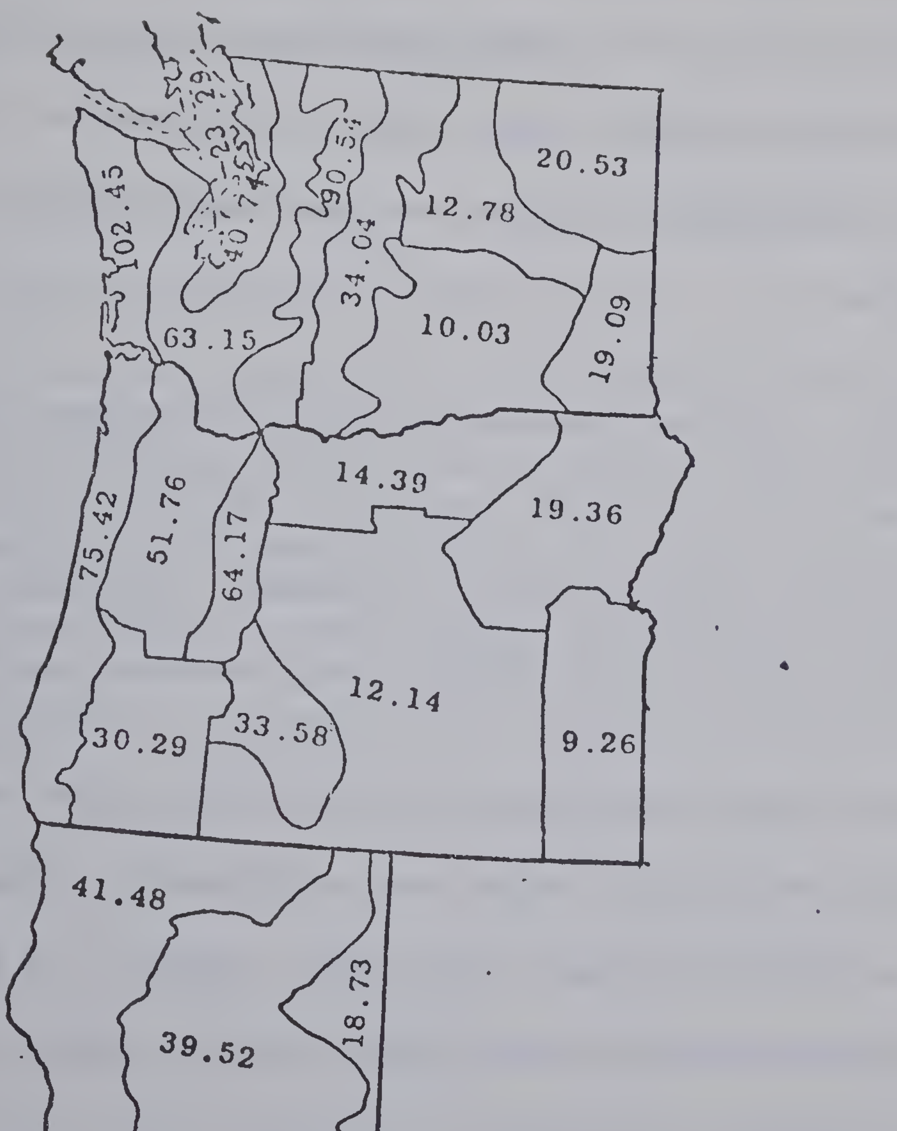


Figure 72. Mean Annual Total Precipitation (inches) for California, Oregon, and Washington. From U.S. Dept. of Commerce (1968).

The first two areas produce storms with winds, occasionally of gale force, which approach the Oregon, Washington and northern California coasts from the southwest. The central and southern California coast is usually not affected by these storms, which prevail throughout the winter months.

Extratropical cyclones, associated with the northern boundary of Pacific high pressure system, generally approach from the west. Winds may also be from the northwest or southwest, depending on the location of the storm center and the Pacific high pressure system.

Tropical hurricanes rarely strike the Pacific coast north of Baja, Mexico. The few that do can be very destructive. One such storm occurred in 1939 with winds of 60 knots. Damage in Los Angeles from this storm was estimated at $1,500,000 (SCOSC, 1974). The principal effects of tropical hurricanes in California are the peripheral winds and swell that reach the coastline.

Thunderstorms are very infrequent along the Pacific coast. In fact, the Pacific States normally experience fewer electrical storms than any other region of the United States (U.S.G.S., 1974). Thunderstorms occur most frequently from late fall through early spring. Along the Oregon and Washington coasts, about eight thunderstorms develop per year, while San Francisco averages about two per year (U.S. Dept. of Commerce, 1963).

c. Physical Oceanography

(1) Surface Sea Temperatures

Surface sea temperatures off the Pacific Coast reflect ocean circulation and wind conditions. During the summer, northern winds induce a southerly flowing current. As the earth rotates under this current, there is a net transport to the west known as the Cariolis force, which in turn induces cold water from the depths to move up to the surface and replace the westerly transport. This upwelling is most pronounced during the spring and summer, causing pockets of cold water (10° to 12°C.) along the coast from central California north to Washington (Fig. 73). Terrestrial runoff and upwelling effectively "push" these cooler water masses into the 14°C. to 16°C. water farther offshore. The warmest continental shelf waters (20°C.) occur off San Diego (Fig. 73).

The Columbia River plume off Oregon and northern California modifies sea surface temperatures to some extent in the early summer. The plume is a thin (down to 20 meters) layer of somewhat fresher, hence less dense water which remains at the surface and resists vertical mixing. This layer is gradually heated by the sun and may be several degrees warmer than adjacent offshore waters (Pearcy and Keene , 1974). The presence of this "tongue" of warm water was very conspicuous in ocean temperature studies made by these investigators during the early summer months when river discharge reaches its maximum.

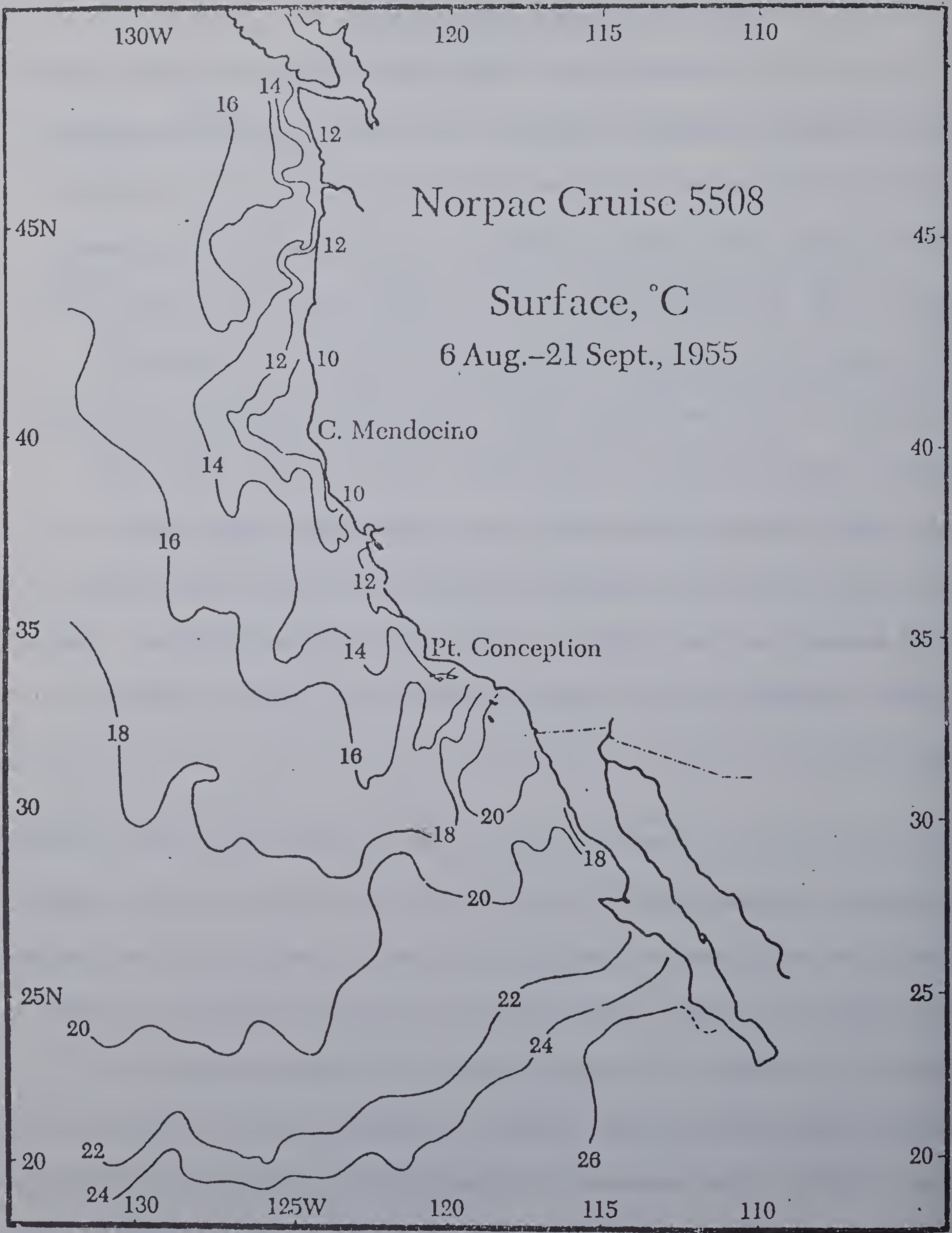


Fig.73. Smoothed isotherms for summer surface temperatures in the eastern Pacific. (Ricketts et al., 1968)

During the fall and continuing into the winter, sea temperatures cool as winds change from the north to the west and southwest. However, upwelling ceases and offsets the seasonal cooling, so that water temperatures between summer and winter are very similar out to about 20 miles from shore (Fig.74). Farther offshore beyond the region of upwelling, water temperatures in winter decrease by about 4° from their summer maximums.

In winter and early spring, cold waters near the shore are shifted north and offshore as a relatively warm northward current (Davidson Current) develops near shore (Fig. 74). This northward current appears to be the result of a weakening of the southward surface current, and is reinforced by southerly winds.

Warmest waters of the Pacific coast occur off southern California in all seasons. Temperatures range from 15°C. in the winter to 20°C. in the summer. By comparison, temperatures off Washington range from 8°C. in the winter to 16°C. in the summer.

(2) Salinity

Surface (0-10 meters) salinities of the Pacific offshore areas range from about 33^{o}/oo to 34^{o}/oo. Variations occur where major rivers flow into the sea and where summer upwelling is intense. Salinity differences are largest during the summer months, when maximum runoff and upwelling occur. Salinities in winter are

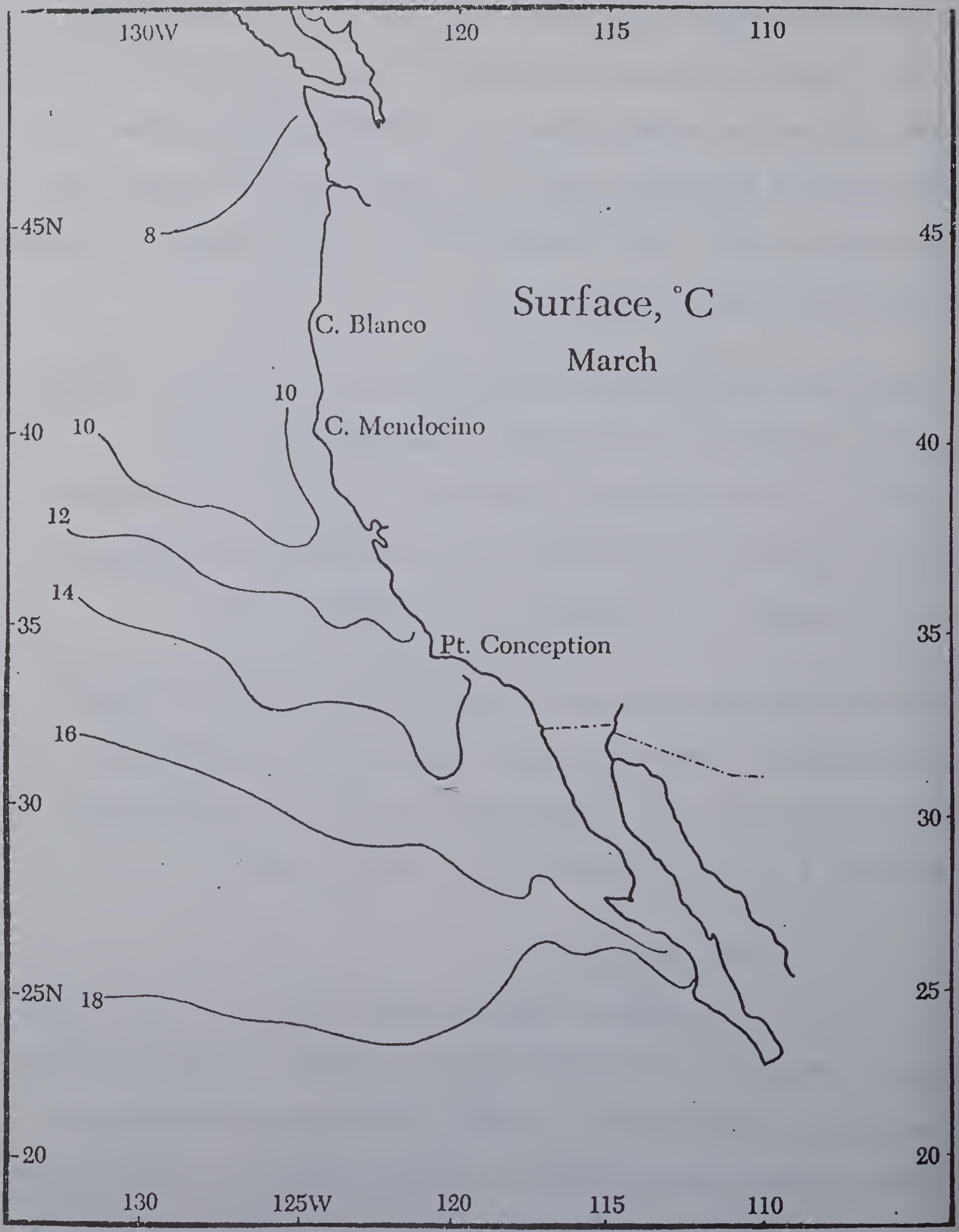


Fig.74. Smoothed isotherms for March surface temperatures in the eastern Pacific. (Ricketts, et al., 1968)

fairly consistent along the entire coast, with a gradual decrease towards the northern latitudes.

In the summer, there appears to be a salinity regime composed of three rather distinct zones. Nearshore salinities off California are about 33.8^{o}/oo, due to the upwelling process which brings cold, saline water up from the depths. Beyond this zone of upwelling, salinities decrease somewhat (33.4^{o}/oo), representing cool subarctic surface waters carried south by the California Current. The third zone, several hundred miles from shore, exhibits the highest salinities (33.8^{o}/oo). This water is away from the influence of runoff and ice melt. Evaporation exceeds precipitation, increasing the salinity.

Barnes, et al. (1972) examined the oceanic areal and seasonal distribution of the Columbia River discharge off Oregon and Washington. This freshwater flow into the ocean has a considerable effect on the salinity distribution. A large, low-salinity plume (32.5^{o}/oo) extends over 200 miles to the southwest of the river mouth during the summer. Essentially, this enhances the three-zone salinity regime discussed above, in that the middle zone is considerably fresher off Oregon and northern California than off southern California.

During the winter months the flow of the Columbia River is greatly reduced. Its discharge moves northward along the Washington coast under the influence of the prevailing southerly winds and the Davidson Current.

(3) Surface Circulation

Water of the north Pacific Ocean is driven eastward by the prevailing westerly winds until it encounters the North American Continent (Fig. 75). At approximately 45° N latitude (about 50° in the summer; 43° in the winter) the flow branches into the northward Alaska Current and the southward California Current. (For reference, the Columbia River mouth is about 46° N latitude). The offshore waters of Washington lie on the southern margin of the Alaska Current during the winter months, but this current has little influence here because of its transitional state, low speed, and the effects of local weather conditions.

The California Current is a meandering, diffuse, variable, and poorly defined flow easily influenced by the wind (Boisvert, 1969). It is a shallow current, with more than 90% of the transport above 300 meters (Sverdrup, et al., 1941). The resultant direction is south, roughly parallel to the coastline. Velocities along the coast (within 60 miles) are usually less than 0.5 knots, and are somewhat higher than those reported farther offshore (U.S. Dept. of Commerce, 1961).

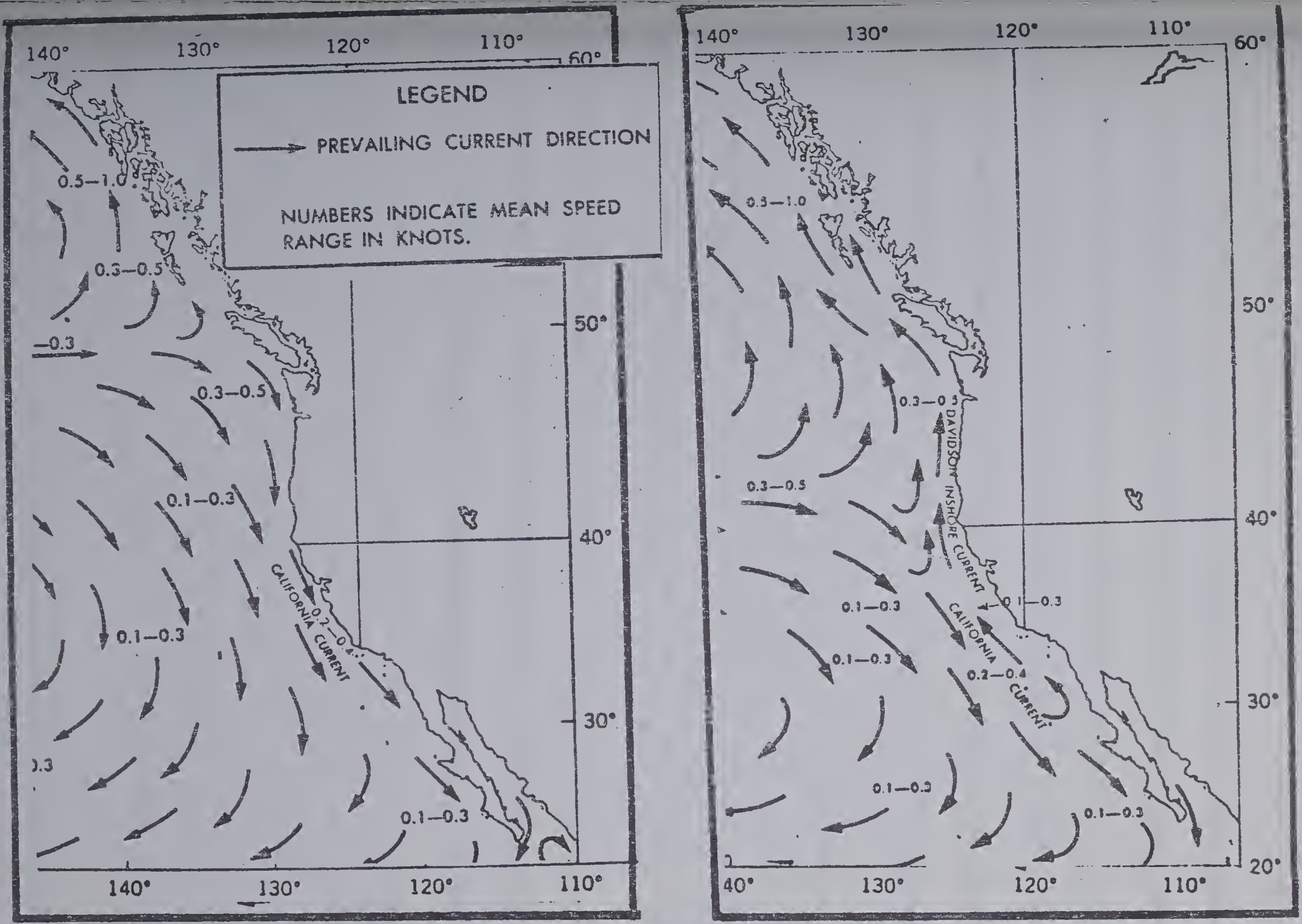


Figure 75 . Surface circulation along the U.S. Pacific coast. Adapted from U.S. Dept. of Commerce (1961).

Variations in direction and speed of the California Current are common. However, there are two well-known and semi-permanent current patterns which are of importance. These are the Southern California Countercurrent and the Davidson Current. The former current forms in the summer months along the Souther California-Mexican border. Part of the California Current is deflected to the left at this point and flows to the north into the Santa Barbara Channel, thus creating a large gyre or eddy. At the northern end of the Channel, water flows out to rejoin the California Current, or continues inshore of the Channel Islands to complete the gyre. During the winter months the Southern California Countercurrent becomes nearly indistinct from the flow of the Davidson Current.

The Davidson Current is strictly a winter occurrence from the tip of Baja California to about 50° N latitude (Fig. 75). Like the California Current, the Davidson Current is sparodic and ill-defined, dependent mainly on the influence of the wind (Boisvert, 1969). The flow is confined to a narrow zone along the continental margin. It is thought to be a vertical extension of the northward flowing undercurrent in this region (Reid, et al., 1958). Current speeds generally average about 0.5 knots.

(4) Tides

The tides along the Pacific coast are classified as semi-diurnal and mixed. This implies that the sea level rises and falls twice each lunar day (24.84 hours) and that successive high (or low) water levels are not equal. The magnitude of the inequality depends primarily on the declination of the moon (angle between the moon and the north-south axis of the earth). The greatest inequalities occur when the moon is at its maximal north or south declination.

Along the outer Pacific coast, the average high tide exceeds the low tide by about 5 feet off southern California, and about 7.5 feet off the coast of Washington (U.S. Dept. of Commerce, 1968). Extreme variations of 10 to 14 feet may occur once a year, usually in December when the sun is closest to the earth. Although the sun's influence on the tides is not as great as the moon's, it is this time that the maximal combined gravitational attraction occurs.

The tides may be considered as a very long "wave", with the high and low tide corresponding to the wave crest and wave trough, respectively. The crest moves along the Pacific coast from the south to the north, such that high water off Washington occurs three to four hours after high water in southern California.

Local variations in coastal topography play an important part in determining the actual tide height at any specific location. Coastal bays, narrows, and estuaries tend to "funnel" the tide, resulting in higher than expected water levels. For example, in Alaska's Bristol Bay, Amak Island experiences a mean tide range of about 5 feet, while in the Naknek River entrance, at the apex of the Bay, tides reach about 18 feet (U.S. Dept. of Commerce, 1971a). These stations are both located in Bristol Bay and are about 300 miles apart. Such extreme tides are not present from southern California to Washington.

Accompanying the rise and fall of the tide are substantial horizontal movements of the sea known as tidal currents. In general, the larger the vertical tide range, the stronger the tidal currents. Because offshore tidal heights are very small (usually less than one foot), offshore currents are likewise of little significance. Velocities range from 0.4 knots off San Francisco to 0.9 knots at Swiftsure Bank (Washington), as indicated by measurements from offshore lightships (U.S. Dept. of Commerce, 1971b).

(5) Sea and Swell

Sea refers to the waves generated locally in an area, while swell refers to the waves generated in a distant region and traveling through an observation point. Sea tends to be choppy and irregular, whereas swell waves tend to have lower crests and are more regular and symmetrical.

Sea and swell are both manifestations of the winds. Therefore, wave conditions off the Pacific coast reflect the prevailing wind conditions to a large extent. (The wind regime has been discussed previously.) However, swell may arrive at the Pacific coast from distant storms in the Gulf of Alaska, the central North Pacific, and the southern Pacific Ocean. The two former locations generate swell most often in the winter months while the swell from the southern Pacific occurs most frequently during the summer months of the northern hemisphere (austral winter). Rough sea conditions occur most frequently during the stormy months of winter.

Figures 76 and 77 show sea and swell roses for the U.S. Pacific coast. A comparison of the roses indicates several general conclusions. The most important are: sea waves generated by local storms are generally higher than the wave heights of swell; the highest waves occur in the winter, and arrive from south and southwest; seas and swell off Oregon and Washington tend to be respectively greater in winter and calmer in summer than off California.

The above conclusions are very general and do not reflect wave modification or amplication that occurs by local topography, such as promontary points, canyons and river mouths. Furthermore, the observations used to compile Figures 76 and 77 were derived primarily from ship reports which are biased toward good weather shipping routes. North Pacific storms can be severe; a 95-foot wave has been recorded from an offshore drilling platform in this area (Ocean Industry, 1969).

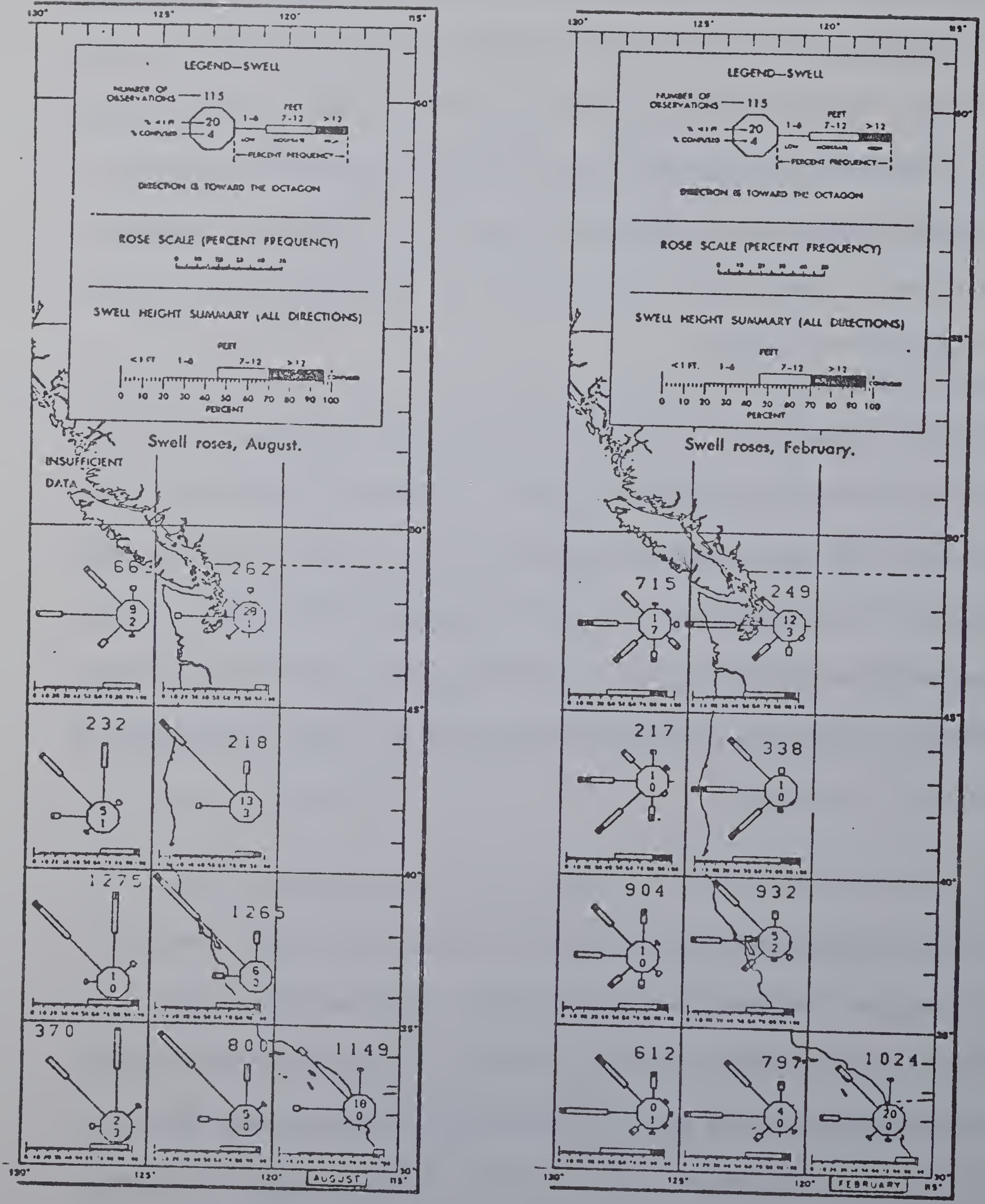
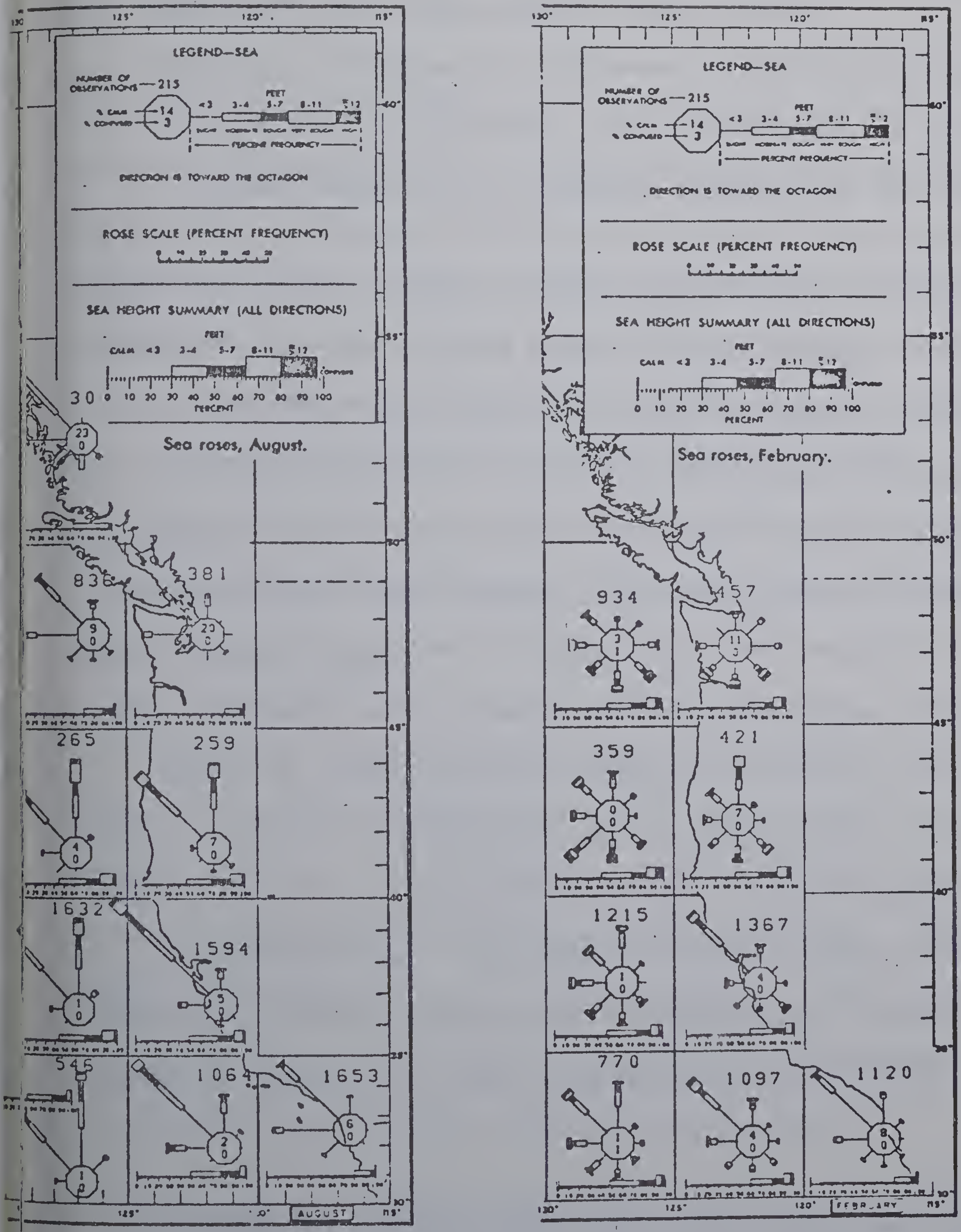


Figure 76 . Swell roses for the U.S. Pacific coast during summer (August) and winter (February). From U.S. Dept. of Comm. (1970).



igure 77 . Sea roses for the U.S. Pacific coast during summer (August) and winter (February). From U.S. Dept. of Comm.(1970).

d. The Biological Environment

(1) Phytoplankton

Waters of the Pacific coast have very large quantities of phytoplankton, especially during spring and summer. These seasons are periods of coastal upwelling and terrestrial runoff which act to replenish nutrients to the surface waters.

Upwelling refers to the vertical motion of water, usually induced by the wind, and occurring typically along western coasts of continents (Smith, 1968). Along the Pacific coast, the predominant wind direction in spring and summer is from the north and northwest. The resulting current moves to the south, but because the earth rotates toward the east, the actual surface water transport is to the west. Subsurface water flows upward from several hundred meters to replace the surface water moving offshore. The subsurface water is cold (10°C.) and rich in phosphates and nitrates, nutrients which generally limit the growth of phytoplankton. Upwelling thus acts as a "conveyor belt", constantly replenishing nutrients to the coastal waters during periods of upwelling. The combination of abundant nutrients and adequate sunlight allows prolific phytoplankton growth (several million cells per liter) in the upper 50 meters of water.

Upwelling is not restricted to the summer months, although it is most intense during that period, especially in the Pacific northwest.

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In southern California the period of greatest upwelling and consequently greatest standing crop of phytoplankton occurs earlier during May and June (Ricketts, Calvin, and Hedgpeth, 1968).

W. E. Allen of Scripps Institute of Oceanography, studied and reported on the phytoplankton of southern California from 1921 to 1946. Among his conclusions (summarized by Riznyk, 1974) are the following. Maximum numbers of phytoplankton were found between 10 and 20 meters in shallow water, and 20 to 30 meters in deeper waters. In 20 years of daily collecting, only 100 species representing 41 genera were identified. Of these only 17 species were dominant; the genus *Chaetoceros* has the greatest total abundance. There is considerable variability in the annual biomass. Annual production tends to be greatest in the spring.

The Allan Hancock Foundation (1965) also conducted phytoplankton studies on the southern California shelf. Their results were basically similar to those of Allen. Of all individual plankters counted, 54% were diatoms and 41% were dinoflagellates. Very large "blooms" were generally due to a single species. They found the diatom *Nitzschia* sp. to be the most widely occurring species. The most abundant dinoflagellate was *Prorocentrum micans*.

Similar studies off Oregon and Washington indicate that diatoms are the most abundant phytoplanters off the Pacific northwest coast, with dinoflagellates being the second most abundant (Anderson, 1972). Dinoglagellates such as Gonyaulax emit toxins. When these plants "bloom", they color the water red and may produce sufficient toxin to kill other marine organisms. This condition is referred to as a "red tide".

The ecology of phytoplanton in the Pacific northwest is somewhat more complicated because, in addition to upwelling, nutrient-laden fresh water enters the coastal water from rivers. The most important freshwater source in the region is the Columbia River. During peak runoff in the spring and summer months, the discharge extends as a plume flowing to the southwest. Phytoplankton generally exhaust its nutrient supply beyond 45 miles from the river mouth (Small and Curl, 1972). Away from the mouth of the Columbia, chlorophyll concentrations are generally kept high inshore by upwelling in summer and by coastal runoff in winter.

The production of phytoplankton can be measured as grams of carbon converted to organic matter (via photosynthesis) per unit area of sea surface (grams C/m^2). For comparative purposes, the following values are from Anderson (1972) and Curl (1970). Waters off southern California have an annual production of 200 to 400 grams C/m^2; the waters off the Oregon coast (out to 25 miles offshore) average 300 grams C/m^2; waters of the continental shelf beyond the influence of upwelling or river runoff average 125 grams C/m^2. These values compare with an oceanic average of 50 grams C/m^2.

Phytoplankton represent the primary food producers in the ocean. From carbon dioxide, water, and solar energy, these plants produce organic matter which is utilized directly or indirectly by nearly everything that lives in the sea. Their importance cannot be overstated.

(2) Zooplankton

Zooplankton biomass is closely related to the biomass of phytoplankton, as the latter serves as the primary food source for zooplankton. Therefore, zooplankton abundances follow phytoplankton abundances, although with a characteristic lag of several weeks, representing an exploitation and utilization phase of the plants by zooplankton.

Zooplankton of the North Pacific have been studied in terms of their relationship to oceanic water masses (major masses of water having measureably unique characteristics). It has been found that each water mass has one or more characteristic zooplankton species associated with it (Johnson and Brinton, 1963). These authors list four distinct faunal zones of the North Pacific: 1) subarctic, 2) transition, 3) Pacific central, and 4) equatorial. None of these zones has fixed geographical zones, but instead are associated with specific temperature-salinity relationships which are characteristic of the water masses. As a consequence, the arctic zone may extend to Baja California if the water mass characteristics are appropriate for arctic water. However, there is some resemblance between the water mass descriptions and the geographical regions.

The Pacific subarctic zone is the more northerly zone, characterized by the copepod species Calanus tonus, C. cristatus, and the euphausiid Euphausia pacifica, among others. These species may at times be found far south in the California Current during the upwelling periods.

The transition zone is a diffuse boundary between subarctic and central populations, but apparently harbors endemic (particular to a specific locality) species; as well as populations of zooplankton common to the zones north and south. A chaetognath, Sagitta scrippsae is endemic to the zone (Johnson and Brinton, 1963), while Calanus pacifica occurs in the subarctic, transition, and central zones but is particularly abundant in the transition zone.

Day (1971) sampled zooplankton off Washington and also found the biomass to be 90% euphausiids, 76% of which were Euphausia pacifica and 14% were Thysanoessa spinifera. Day also concluded that the zooplankton biomass was generally lowest near shore, reached a maximum at or near the seaward edge of the continental shelf, and decreased farther offshore. Brinton (1960) reported a third euphausiid, *Nematoscelis difficilis* was also a member of the faunal assemblage in the transition zone.

Characteristic zooplankton of the central faunal zone include *Euphausia brevia* and *E. hemigibba*. Central zone species are not particularly common off the U.S. Pacific coast, as this water mass is farther south and offshore. Under certain weather conditions, these species may "encroach" upon the southern California coast. Equatorial species, such as *E. eximia*, may also be reported as occasional northern migrants during abnormal warming periods (Brinton, 1960).

In addition to variations in the areal distribution of zooplankton, these animals undergo extensive daily vertical migrations as well. Euphausiids may ascend 500 to 700 meters during the evening, returning to the depths in the morning. Not all species of zooplankton undergo these migrations, while others show a number of variations in vertical migration and depth preferences. The level of illumination is the most accepted "caused" mechanism associated with the vertical movements of zooplankton.

An important segment of the zooplankton biomass is the meroplankton; those organisms which spend part of their lives as plankton, as opposed to holoplankton, which spend their entire lives as plankton. Examples of meroplankton are the larval stages of fish and other large marine organisms. The number and location of these plankters depends in part on the season and prevailing currents. Examples of meroplankton include larvae of crabs, spiny lobsters, sardines, mackerel, anchovy, halibut, and other important commercial fish species. The duration of the larval stage is variable but is generally less than several months.

(3) Benthic Biota

The term benthos refers in general to those organisms living in (infauna) or on (epifauna) the bottom of the sea. Collectively, the animals of this environment make up one of the most complex and least understood areas of marine biology. The complexity arises from the many diverse adaptions of these animals to their environment. These adaption include burrowers, scavengers, filter-feeders, predators, and parasites. In addition to their ecological importance in the sea, benthic organisms are of economic importance also. There are many valuable fisheries for benthic animals, such as shrimp, lobster, and halibut.

Bottom organisms along the Pacific coast are primarily distributed in area and density according to water temperature and type of substrate (sea bottom). Other factors influencing the benthos are water depth, distance from shore, currents, and food availability.

Epifaunal communities reach their maximum development in the intertidal zone, while the infauna dominates the sea floor beyond the subtidal zone (Odum, 1971).

The primary source of food for benthic animals is the continual rain of dead organisms and detritus from above. This material is ingested by the primary consumers such as worms and molluscs. The benthic community is therefore related to the surface water productivity. Surface waters of the U.S. Pacific coast are highly productive because of the upwelling process, discussed in a previous chapter. Correspondingly, a rich benthic community exists in this area.

The benthos of southern California has been relatively well studied by the Allan Hancock Foundation (1965). This is particularly true of the nearshore area orginally termed the mainland shelf (Emery, 1960) which extends from shore to a depth of approximately 300 feet (100 meters). The Allan Hancock Foundation estimated the average standing crop biomass of the benthic macrofauna to be 356 grams/sq. meter. Emery (1960) reported a range in the standing crop of the mainland shelf to be 40-4,000 grams per sq. meter.

The major animal group found on the mainland shelf were the polychaetes. This class of annelid worms was the most widely distributed group, outranking any other group in species, numbers, and total weight. Neary half of all specimens counted were

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polychaetes. Crustaceans, especially phoxocephalid amphipods, accounted for about 25% of all specimens but, because of their small size, seldom comprised more than 5% of the biomass. The small red brittle star Amphioda urtica (Echinoderm, Ophuiroida) was the most abundant single species (being found in 85% of all samples at depths greater than 30 feet) averaging 400 individuals per square meter. Bivalve molluscs were usually so small that they contributed only a small amount to the biomass, even though their shells were included in their weight. The echiuroid worm Listriolobus pelodes was not widespread, but heavily concentrated in the fine sediment near Santa Barbara. The brachiopod Glottidia albida was found in 60% of the samples. The above groups accounted for over 90% of the benthic biomass, and the majority of the 1,200 species that were collected.

Near Santa Barbara the vast majority of specimens, both in numbers and biomass (80%), consisted of the echiuroid worm Listriolobus pelodes. This species remained dominant in 1969 (Fauchald, 1971), but was greatly reduced compared to the early 1960's at the time of the Allan Hancock Foundation study.

Rocky outcrops on the continental shelf in this area are relatively uncommon. Animals on them are composed primarily of epifaunal species. Representative species include: A seastar Asterina, a snail *Astraea undosa*, a brittle-star *Ophiothrix spiculata* and a stalked barnacle, *Scalpellum*. On a silt-stone reef located about 500 meters off Corona del Mar, Pequegnat (1964) reported that between 300 and 400 species were encountered. The major community on the reef-top was formed by the rock oyster *Chama pellucida*.

Sandy areas in depths of 10 to 30 feet are relatively harsh environments due to an unstable bottom which shifts because of wave action. The number of individuals is not significantly lower in comparison with the deeper bottoms, however. The types that have adapted to the shifting sands include those that occupy transient or relatively permanent deep burrows, such as the long-neck clams, or that can burrow quickly, such as the worm *Loima medusa*, or that are spindle-shaped, such as the lancelet *Branchiostoma*, the polychaete worms *Ophelia* and *Nephtys*, and *Sipunculus*, a peanut worm.

The benthic studies of the other areas off southern California are summarized by the Southern California Coastal Water Research Project (1973). The numerous basins and troughs off the southern California coastline are a unique feature of the area. Because of their depth and their depression below the surrounding sea floor, they serve as sinks for organic detritus settling from overlying waters, and the dissolved oxygen in at least three of the basins is extremely low, from less than 0.1 to 0.4 mg/l. The fauna

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found in the basins was far less rich and diverse than that of the mainland shelf, and consisted primarily of polychaetes that could evidently tolerate the low oxygen conditions. The dominant species of the different basins differed remarkedly.

The submarine canyons contain a unique and varied fauna. Hartman's (1963) study showed that 30 to 60 percent of the species found in one canyon were not found in adjacent canyons, indicating some degree of isolation. Canyon habitats are subject to considerable fluctuations in environmental conditions because they serve as natural channels for shoreward movements of upwelling waters and organisms and for downward transport of runoff, sands and debris. These processes result in widely (and often suddenly) varying conditions, to which the indigenous fauna must adjust. In general, the variety and numbers of animals in canyons decrease with depth, as on the shelf and in basins. In all of the canyons, polychaetes represented the largest population of the total number of species; crustaceans and molluscs were present in significantly fewer and about equal numbers. Estimates of biomass in the canyons showed that the canyons are intermediate in standing crop between the basins and the shelf, with an average biomass of about 175 g/sq. m.

The composition of benthic fauna of the central Oregon continental shelf changes with increasing depth and distance from shore (Carey, 1972). The epifauna changes from a sparse molluscan

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assemblage to one dominated by numerous echinoderms and arthropods. The infauna demonstrate a seaward variation in species composition; arthropods are dominant close to shore, and polychaetes are dominant offshore. Abundance increases seaward; the largest numbers and greatest biomass of both epifauna and infauna were found at the outer edge of the continental shelf.

Pereya and Alton (1972) sampled the invertebrate fauna off the northern Oregon coast. They concluded that the distribution of organic carbon in the sediments appeared to be the environmental factor most responsible for the observed distribution of the epifauna.

Lie (1969) and Lie and Kisker (1970) sampled the benthos off the State of Washington and reported three communities which were distributed according to sediment type, depth, and distance from shore. The standing crop at the shallow water stations having fine sand substrates was dominated by crustaceans and small lamellibranchs (clams), whereas the deeper stations with silt-clay substrate were dominated by polychaetes and echinoderms.

According to Lie and Kisker (1970):

> The deepwater mud-bottom community identified previously as one of the three benthic communities off the coast of Washington was found at mean depths of 154.5 m in sediments with a mean mud percentage of 50.09%. The most abundant species were the polychaetes Prionospio malmgreni,

> *Sternaspis fossor*, and *Ninoe gemmea*, the lamellibranchs *Axinopsida serricata*, *Adontorhina cyclia*, and *Macoma carlottensis*, and the amphipod *Heterophoxus oculatus*. The mean standing crop (ash-free dry weight) was 3.058 g/m^2, with the echinoderms *Brisaster latifrons*, *Ophiura lutkeni*, and *Amphioplus* sp. and the polychaetes *Sternapis fossor* as the major contributors to the standing crop.
>
> The intermediate depth sand-bottom community was found at stations with a mean depth of 95.8 m in sediments with a mean sand percentage of 67.81%. The most abundant species were the polychaetes *Magelons* sp., *Sternaspis fossor*, *Nephthys* sp., and *Haploscoloplos elongatus*, the lamellibranchs *Yoldia ensifera* and *Axinopsida serricata*, and the amphipod *Paraphoxus variatus*. The mean standing crop was 2.533 g/m^2, with the species listed above and the lamellibranch *Macoma elimata* as the major contributors to the standing crop.
>
> There was a distinctly lower species diversity in the shallow water sand-bottom community than in the two communities in deeper waters.

Lie pointed out that most shallow water sandy bottoms in other geographical locations have high species diversity. These areas are, however, relatively protected, whereas the shallow water sand-bottom community off the coast of Washington is exposed to heavy wave action. Therefore, in spite of the stability of salinities and temperatures, the community may be considered a "physically controlled community", this type of community generally exhibits a lower species diversity than one which is "biologically controlled", or under lower physical stress.

(4) Active Swimmers - Nekton

The Pacific continental shelf nekton is strongly associated with the California Current and the coastal upwelling of nutrient rich waters. Presently the most numerous epipelagic fish of the California Current throughout California is the northern anchovy, although the Pacific herring is abundant in the Pacific Northwest. Anchovies are abundant off the Washington and Oregon coasts, particularly during the winter (Glude, 1971).

An airborne monitoring system has recently been used to assess the abundance of some pelagic fishes off California (Squire, 1972). Major species include, but are not limited to, Pacific bonito (*Sarda chiliensis*), yellow tail (*Seriola dorsalis*) northern anchovy (*Engraulis mordax*), jack mackerel (*Trachurus symmetricus*), Pacific mackerel (*Scomber japonicus*), Pacific barracuda (*Sphyraena argentea*) and squid (*Loligo opalescens*). Summer tuna migrants into the coastal regions include the bluefin tuna *Thunnus thymus* and albacore *Thunnus alalunga*. (The latter can be numerous off the Pacific Northwest, also.)

Some crustaceans such as the ocean shrimp (*Pandalus jordani* spend much of their time as members of the pelagic community, but the most important are pelagic red crabs (family Galatheidae).

According to Frey (1971):

> It has been estimated that a floating otter trawl with a 326-square-foot mouth could catch at least 2.5 tons per trawling hour. This catch could be made by fishing selectively in areas where the pelagic red crabs are "swarming". Higher catch rates to 25 tons per hour have been suggested for demersal otter trawl fishing in upwelling areas and at depths that correspond to the oxygen minimum. These catch rates have been verified by field experiments in the California Current.

The midwater fauna off southern California is especially complex because it contains species from three converging water masses (Pacific Subarctic, North Pacific Central, Pacific Equatorial) as well as species endemic to the California Current system (Lavenberg and Ebeling, 1967). Lavenberg and Ebeling recognized specific groups of species associated with each of these water masses.

According to Miller and Lea (1972), there are 554 species of coastal marine fishes known to occur in California. This count includes only part of the mid-water fauna, so the actual number of species is larger. The number of species decreases in a south to north direction, continuing off Oregon and Washington.

Considering the continental shelf demersal species (those fish associated with the bottom) SCCWRP (1973) reported 121 species off southern California to a depth of about 300 meters. Alton (1972), sampling in an area having fish typical of both Oregon

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and Washington, reported 92 species of demersal fishes from a depth interval of 91 to 2,121 meters. Alton summarized his important study as follows:

> The Cottiformes, or mail-cheeked fishes (rockfish, sable fish, lingcod, sculpins, and others), were the most diversified (37 species) of the fish groups in the study area and contributed substantially to the total number of fish species found from most depths. The rockfishes (Scorpaenidae) in particular were strongly represented (17 species) in trawl catches from the edge of the continental shelf (100 to 175 fathoms; 183 to 320 m). Gadiform fishes (Macrouridae and Moridae) accounted for half the number of species taken from abyssal depths of 1,050 and 1,160 fathoms (1,920 and 2,121 meters). The greatest diversity of fish species (40 to 43) was from the outer continental shelf and upper slope (50 to 175 fathoms; 91 to 320 meters). After a sharp drop to 28 species at depths of 200 to 225 fathoms (366 to 411 meters), the number of fish species encountered gradually decreased with increasing depth. Only 8 to 11 species were encountered from abyssal depths (900 to 1,160 fathoms; 1,646 to 2,121 meters).
>
> The largest accumulations of fish in the study area were obtained from the bottom depth interval of 50 to 225 fathoms (91 to 411 meters), where average trawl catches ranged from 2,000 to 3,000 lb. per hour trawled. Important components of the catches from this zone were the Pacific hake (*Merluccius productus*) from 50 to 175 fathoms (91 to 320 meters); flounders from 50 to 225 fathoms (91 to 411 meters); rockfish, mainly Pacific ocean perch (*Sebastodes alutus*) from 100 to 225 fathoms (183 to 411 meters). A secondary zone of fish abundance (500 to 1,000 lb. per hour trawled) occurred at 250 to 425 fathoms (457 to 777 meters), where sablefish (*Anoplopoma fimbria*) comprised most of the fish caught. Catch rates of 200 lb. per hour and less were obtained from bottom depths of 600 to 1,160 fathoms (1,097 to 2,121 meters). Longfin cod (*Antimora rostrata*) and rattails (*Macrouridae*) were predominant in catches from these depths.

> Major changes in the availability of fish occurred from the outer continental shelf and upper slope region (50 to 225 fathoms; 91 to 411 meters) and were seasonal. Low catch rates from these depths were consistently obtained during the winter sampling periods, whereas high catch rates were usually obtained during the summer sampling periods. These changes in fish availability were interpreted as due partly to bathymetric and latitudinal shifts in the populations of several species, such as the Pacific hake , Dover sole (Microstomus pacificus), turbot (Atheresthes stomias), and sablefish. No seasonal change in the availability of fish from bottom depths of 250 to 475 fathoms (457 to 869 meters) was found. The deepwater stations (600 to 1,160 fathoms; 1,097 to 2,121 meters) were only sampled during the spring and summer months.

According to Walker (1962) there are 30 species of North American whales and dolphins on the Pacific Ocean. Seven of these species are threatened with extinction, according to the Fish and Wildlife Service (See section III.1b6). Perhaps the most famous is the gray whale which migrates close to shore.

The Pacific coast is a haven for pinnipeds (sea lions, seals) and a sea otter. South of Point Conception, California, mainland breeding areas are no longer in existence because of human habitation. Breeding areas are confined to the offshore islands, particularly San Miguel and San Nicolas Islands (Carlisle and Aplin, 1970). San Miguel has the largest populations and the most species (five) of these mammals. The most important (numerous) seals of southern California are elephant seals and the California sea lion. North of Point Conception pinnipeds still breed on certain mainland areas. Farther north, the California sea lion becomes less abundant than the Stellar sea lion, while the fur seal becomes abundant. Several smaller offshore rocks or islands, including the Farallon Islands, are also important breeding areas in the northern part of the Pacific coast.

(5) Birds

The Pacific coast of the United States between the Mexican and Canadian borders is typified by a large and varied composition of marine-associated bird life. As one proceeds north from Southern California the type of habitat available for marine birds increases. Offshore rocks, inlets, islands, and extensive areas of undeveloped and often inaccesable coastline increase, providing ideal habitat and breeding sites for birds. Oceanographic conditions along the Pacific coast from Point Conception (in Southern California) to Washington produce extensive areas of nutrient-rich upwelling. This factor provides ocean waters rich in marine life and conducive to supporting large migrant and breeding populations of sea birds.

In Southern California the predominant available habitats are sandy beaches and coastal wetlands which receive heavy human population pressures. This environment is a less desirable habitat than the more desolate coastlines to the south. Straughan (1971) reported the following population figures for the Santa Barbara Channel area of Southern California:

> The California Department of Fish and Game carried out aerial and beach surveys of the bird population in the Santa Barbara Channel commencing February 5, 1969. Avian population for the 1,075 square miles sampled by the aerial transects was estimated to be 12,000 birds. Species groupings in order of their abundance were gulls, shorebirds, waterfowl, loons and grebes, cormorants and pelicans, and other waterbirds.
>
> Significant bird population movements were recorded on aerial surveys between April 1 and May 31, 1969. A number of species wintering in the Channel area migrated by the end of May to their breeding grounds further north. A large influx of pelagic birds, notably sooty and pinkfooted shearwaters was noted offshore. Birds counted on aerial surveys averaged 5,242 per day as compared to 3,490 for the first report period. Estimated bird population in the Channel area sampled was 85,000 for this period.

In addition to nesting seabirds, the coastal zone and offshore areas are utilized during different periods of the year by a large host of resident and migratory waterfowl, shorebirds, and terrestrial birds.

The Point Reyes Bird Observatory located on the coast just north of San Francisco has for the past ten years been involved in bird census and banding studies on the offshore Farallon Islands and coastal areas near Point Reyes. Stewart (1971) listed the following

[redacted]

birds as a few of the typical Pacific coast migrants found at Point Reyes: western flycatcher, warbling vireos, white crowned and golden crowned sparrows, and hermit thrushes. Page (1971) cited the following shorebirds as a few of the Pacific coast recorded migrants for Bolinas Lagoon north of point Reyes: western pectoral, and least sandpipers, northern phalaropes, willets, whimbrels, dowitchers, marbled godwits, black bellied plovers, and black turnstones.

Reynolds and Osborne (1971) listed in order of importance the following breeding seabirds for California: Cassin's auklet, common murre, western gull, Brandt's cormorant, Leach's petrel, ashy petrel, pelagic cormorant, pigeon guillemot, fork tailed petrel, rhinoceros auklet, double crested cormorant, tufted puffin, and black oyster catcher. The largest population of seabird breeding pairs in the State occurs in the two northernmost counties of Humboldt and Del Norte. Castle Island in Del Norte County is second only to the Farallon Islands off San Francisco for total number of seabird breeding pairs in California. (Osborne, 1971).

Essentially the same species composition of colonial breeding sea birds are in the States of Oregon and Washington. The U.S. Fish and Wildlife Service (April, 1972) cited colonial seabirds as being the most abundant birds present on the Oregon Islands National Wildlife Refuge (see section on refuges). These represent eighteen colonial species with over half of them breeding along the Oregon coast. The most common in order of abundance are: Leach's petrel, common murre, fork tailed petrel, western gull, Brandt's cormorant, pelagic cormorant, glaucous-winged gull, tufted puffin, and pigeon guillemot.

For the Washington Islands National Wildlife Refuge, the U.S. Fish and Wildlife Service (June, 1973) cited 14 different species of colonial breeding seabirds. In order of abundance they are: Leach's petrel, rhinocerous auklet, tufted puffin, fork tailed petrel, common murre, glaucous-winged gull, western gull, Brandt's cormorant, pelagic cormorant, Cassin's auklet, black oyster catcher, pigeon guillemot, double crested cormorant, and the hybrid glaucous-winged western gull. Over 150,000 breeding pairs are listed as populating this area.

The U.S. Fish and Wildlife Service conducts yearly bird censuses for many areas of the Pacific coast. Their census figure for peak population numbers for the Washington Islands National Wildlife Refuge during the 1973 fall migration and 1974 spring nesting periods, were 980,000 and 180,000 birds respectively. Total peak population census figures for the Oregon Islands National Wildlife Refuge during the fall of 1972 and the spring of 1973 were 1,215,000 birds. (U.S. Fish and Wildlife Service, 1973; 1974). These figures reflect marine associated nesting and migrant populations and excludes waterfowl population numbers.

The largest single species of bird represented in the migrants are the shearwaters which pass along the Pacific coast on their seasonal migration from Alaskan waters south to their breeding grounds in the Southern Hemisphere.

The States of Washington, Oregon and California make up the Pacific flyway for waterfowl in the United States. Ducks and geese using the Pacific flyway breed during the summer months in the prairie provinces of Alberta and Saskatchewan, Alaska, the Yukon, parts of the Northwest Territories, British Columbia, Siberia and in the flyway States (California Dept. of Fish and Game, 1970). Each fall, about 10 million ducks and one million geese come to winter in the interior portions of California.

Those birds originating in Siberia, Alaska, the Yukon and the Northwest Territories of Canada utilize the coastal wetlands of Oregon and Washington and, in particular, the coastal wildlife refuges such as Willapa National Wildlife Refuge on the central Washington coast. Portions of these migrants continue down the length of the Pacific coast to winter on the coastal wetlands of southern California.

In summary, the coastal zones and offshore areas of California, Oregon and Washington host a large population of marine associated birds and waterfowl. This is due to an abundant marine food supply, extensive areas of inaccessible coastline and offshore rocks, and low human population pressures. The majority of the offshore seabird breeding and roosting sites in Oregon and Washington are part of the Federal refuge system.

(6) Unique Environments

It is difficult to establish unique environments. The whole Pacific coast, with its water temperature, current, upwelling, rocky shores, etc., is unique, being substantially different from the other coastal areas of the United States.

Within the Pacific coast region, there are certain features which are extremely important to the environment of the Pacific coast.

1. Kelp Beds: One of the most important habitats to the Pacific coastal areas are the kelp beds. Extending from just past the surf zone to depths of 100 feet, these plants form an association for numerous species and individuals of fish and invertebrates. Standing crop estimates of resident fishes in kelp beds are close to values for lakes and coral reefs. Incorporating invertebrate biomass into this figure would increase the standing crop value many times (Quest, 1968). South of Point Reyes, California, the giant kelp (Macrocystis) is the most numerous genus while north of this point bull kelp (Nereocystis) becomes the dominant genus.

2. Offshore Islands and Rocks: The eight offshore islands of southern California are essentially the only remaining relatively-unaltered coastal and associated upland habitats remaining in this region. These islands and the numerous offshore rocks along the remaining Pacific coast serve as important and sometimes the only remaining breeding and hauling out regions for seals and sea lions, and are extremely important nesting areas for sea birds. Guadalupe Island is the main breeding ground for the Guadalupe fur seal, which is an endangered species. Anacapa and Santa Barbara Islands are in the Channel Islands National Monument.

3. Subtidal Rock Outcrops on Banks: Scattered along the Pacific continental shelf, usually near its outer edge, are shallow rocky banks rich with attached organisms and associated fish. Tanner and Cortez Banks off southern California are typical of this type of environment. Off San Francisco are the Farallon Island shoals and Cordell Bank; off Oregon are Heceta and Stonewell Banks.

4. Submarine Canyons: Submarine canyons such as Scripps, Newport, and Monterey, are also scattered along the continental shelf of the Pacific coast. These may be considered unique environments, because of the proximity

of deep water and steep rocky submarine cliffs, literally a few hundred yards from the beach.

5. Bays and Estuaries: In southern California there are only a few estuaries which, like Mugu Lagoon, are unaltered. These are unique for the area. Several other estuaries (San Francisco Bay, Willapa Bay), are important to marine bird migrations because of their size, or to fisheries and offshore hydrology (Columbia River Estuary).

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e. Natural Phenomena Unique to Area with Potential to Cause or Contribute to Environmental Impacts of Proposed Action

Natural phenomena with the potential to cause or contribute to environmental impacts are primarily geologic (such as earthquakes, natural oil seeps, landslides), meteorological (winds, tropical hurricanes), and oceanographic (waves, tsunamis). These phenomena and their effects have been discussed in Sections II A 3 a, II A 3 b, and II A 3 c, respectively. The sections include natural phenomena associated with the nearshore environment, in addition to the offshore environment.

4. Alaska Region

a. Geology

General

Alaska is situated at the northern end of the American Cordillera--the continuous mountain system which extends the entire length of western North and South America. As such, Alaska is similar, both structurally and physiographically, to other parts of the mountain complex. Table 22 relates analogous features of the Alaskan and conterminous U.S. cordilleran sections. Dynamic earth processes continue to alter both regions; the Aleutian Island arc is one of the most seismically active (earthquake-prone) areas of the world (see Fig. 78), while noticeable movement along active fault zones in central and southern California occur continually.

Seismic events in these two widely separated regions can be related to active areas in other parts of the world by the modern Theory of Plate Tectonics.

Plate Tectonic Theory

Both the San Andreas fault system in California and the Aleutian Arc Trench south of the Alaskan peninsula-Aleutian Island chain form parts of a continuous, world-wide system of faults, rifts, and deep ocean trenches. These features define the boundaries

TABLE 22 ANALOGOUS NORTH AMERICAN CORDILLERAN FEATURES

Alaska	Western U.S.
Arctic Coastal Plain	Interior Plains
North Slope	High Plains of Colo., Wyo., Mont.
Brooks Range	Rocky Mountains proper
Yukon-Tanana Valley	Columbia Plateau/Basin and Range Province
Aleutian Island Chain/ Alaska Range	Cascade-Sierra System
Coastal Trough	Puget Sound-Willamette-Great Valley (Cal.) Lowland
Pacific Border Ranges (Chugach, St. Elias, Kenai Mts.)	Olympic Mts.-Coast Range of Wash., Ore., Cal.)

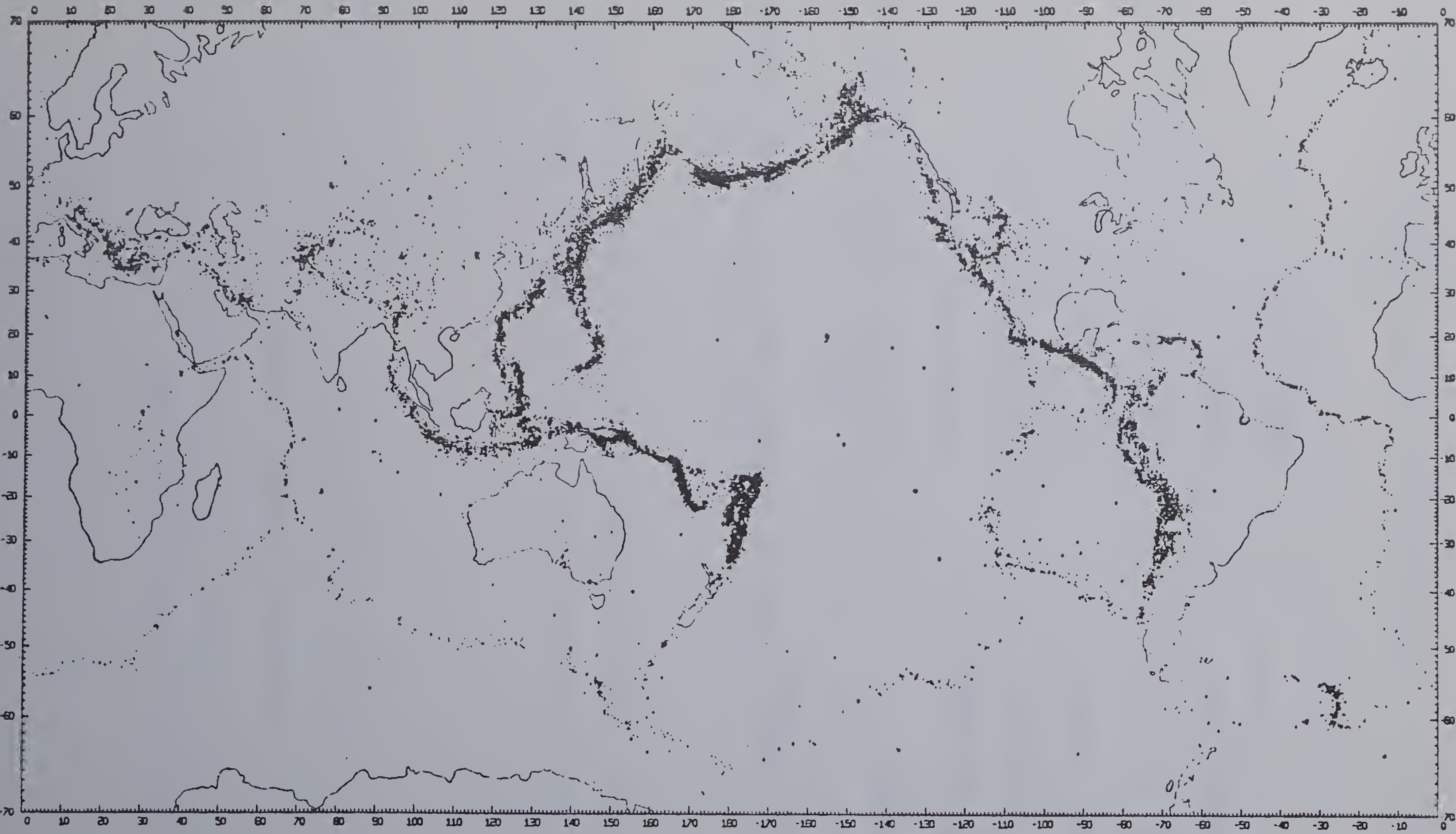


Figure 78 . **Worldwide distribution of all earthquake epicenters for the period 1961 through 1967 as reported by U. S. Coast and Geodetic Survey** (from Isacks, et al., 1968; after Barazangi and Dorman, 1969).

between high shifting plates which collectively comprise the earth's lithosphere, an approximately 100 km-thick zone of rigid to semi-rigid rock material which is supported by and moves about upon a non-rigid substratum termed the asthenosphere.

Although certain details of the theory have not been resolved 1/, an impressive body of geological and geophysical evidence has accumulated in support of its basic concepts.

Interactions along plate margins can be characterized as one of three types of relative movement: divergent, convergent or lateral. Areas of divergence or "spreading centers" occur primarily as linear rifts in deep ocean areas where the earth's crust is relatively thin (5 km vs. 30-35 km beneath continents). Here, tensional forces cause a separation and general elevation of adjacent plat margins as "new" molten crustal material wells up into the intervening cracks.

Areas of plate convergence are characterized by extreme compressive forces. Depending upon the velocity of convergence and nature of

---

1/ The most persistant problem to date has been to define the energy source or driving mechanism for plate movements. This energy is thought to be related to convective heat transfer within the earth's mantle, the 1800 miles (2900 km) thick section of the earth's interior lying between the crust and outer core.

rock materials involved, plate convergence can result in either buckling of the plate margins, creating mountains or the subduction (underthrusting) of one margin beneath the other (Fig. 79). Since large compressional forces are involved, subduction usually involves the thrusting of relatively weak oceanic crust beneath continental margins. This process is currently taking place in the northern Pacific area beneath the Aleutian Island arc. Here, as in most other subduction zones, underthrusting is evidenced by the presence of a deep, arcuate trench (Aleutian Trench) trending perpendicular to the direction of plate movement. A characteristic zone of active volcanism parallels the trench, to the landward side.

The third type of plate boundary occurs in areas where one crustal block segment slides laterally past another. This situation is exemplified by the San Andreas Fault system in south-central California where the North Pacific plate, including that part of California to the west of the fault, is moving northwest with respect to the North American plate to the east. Extrapolating present-day plate movements, Dietz and Holden (1970) estimated that, in 60 million years, Los Angeles will begin to slide into the Aleutian Trench.

Relative rates of plate motion in various parts of the world are estimated at only several centimeters per year. Even at these

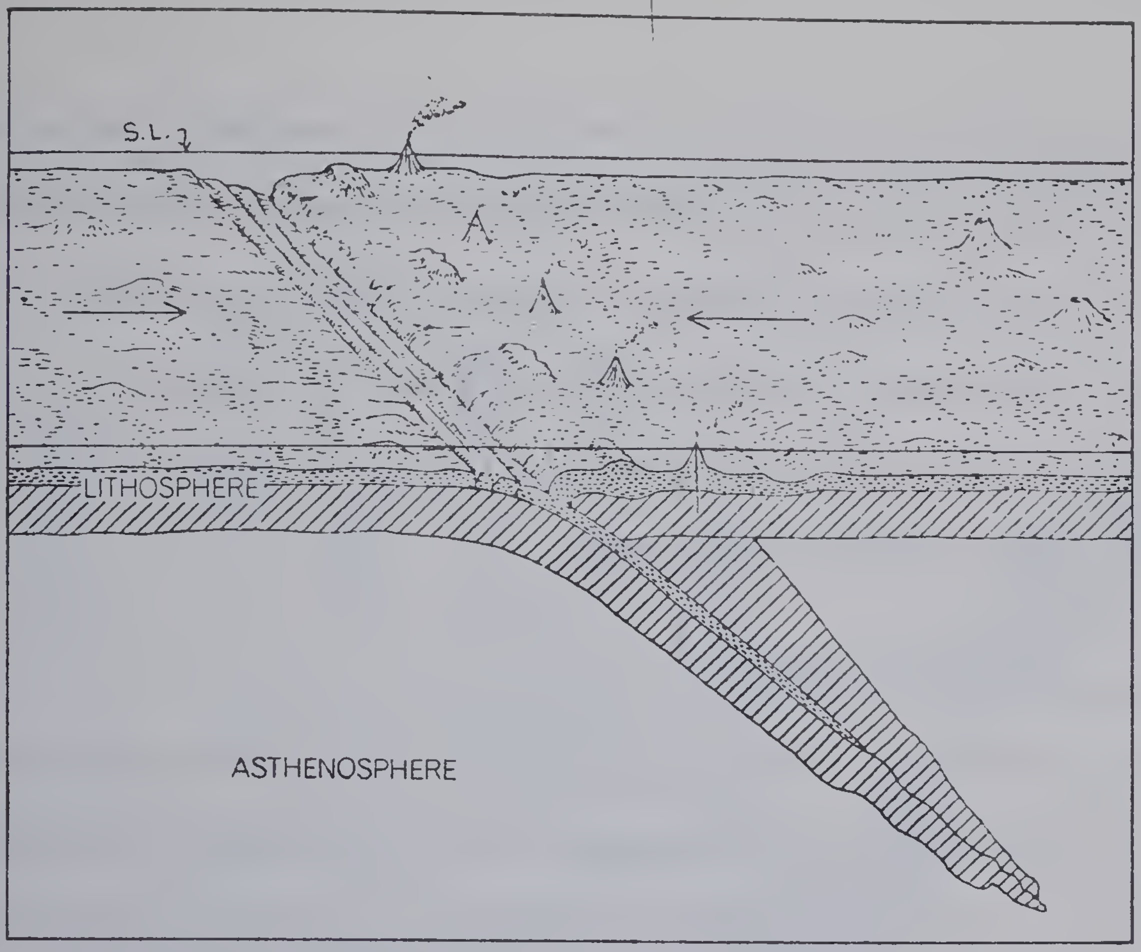
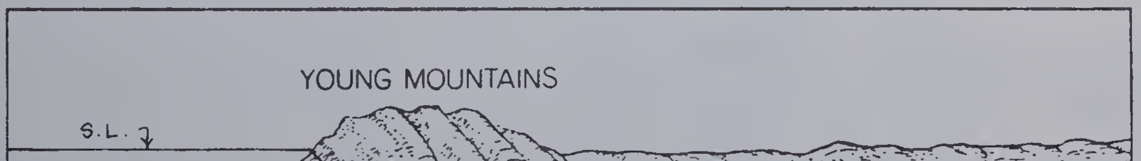


Figure 79. (a) Creation of trench resulting from rapid convergence of plate margins.



(b) Mountain range formation resulting from slow convergence of plate margins where the lower energies created by collision can be absorbed through buckling. (from Menard, 1969).

slow rates, however, prolonged periods of lithospheric adjustment have resulted in some impressive geomorphic changes on the earth's surface. Two prominent examples are the opening and growth of the Atlantic Ocean basin during the last 200 million years and the buckling of the colliding continental margins of India and Asia that formed the Himalayas.

Geologic Hazards in Alaska

Geologic hazards that may occur in present and future production areas of the Alaskan OCS are likely to be significant. The southern Alaska coast is characterized by frequent earthquakes, fault offset and local volcanism. Further north as seismic hazards diminish, problems related to the distribution and nature of permafrost demand more attention.

Permafrost

Permafrost refers to the permanently frozen zone of soil, subsoil, or other earth materials which underlie much of the higher-latitude regions of the world. Areal distribution of permafrost in Alaska varies considerably. Much of the northern and western sections of the State are underlain continuously, while southern areas are virtually free from its occurrance (Fig. 80). Permafrost distribution in the remaining parts of Alaska is quite variable, ranging from isolated patches to broad discontinuous areas.

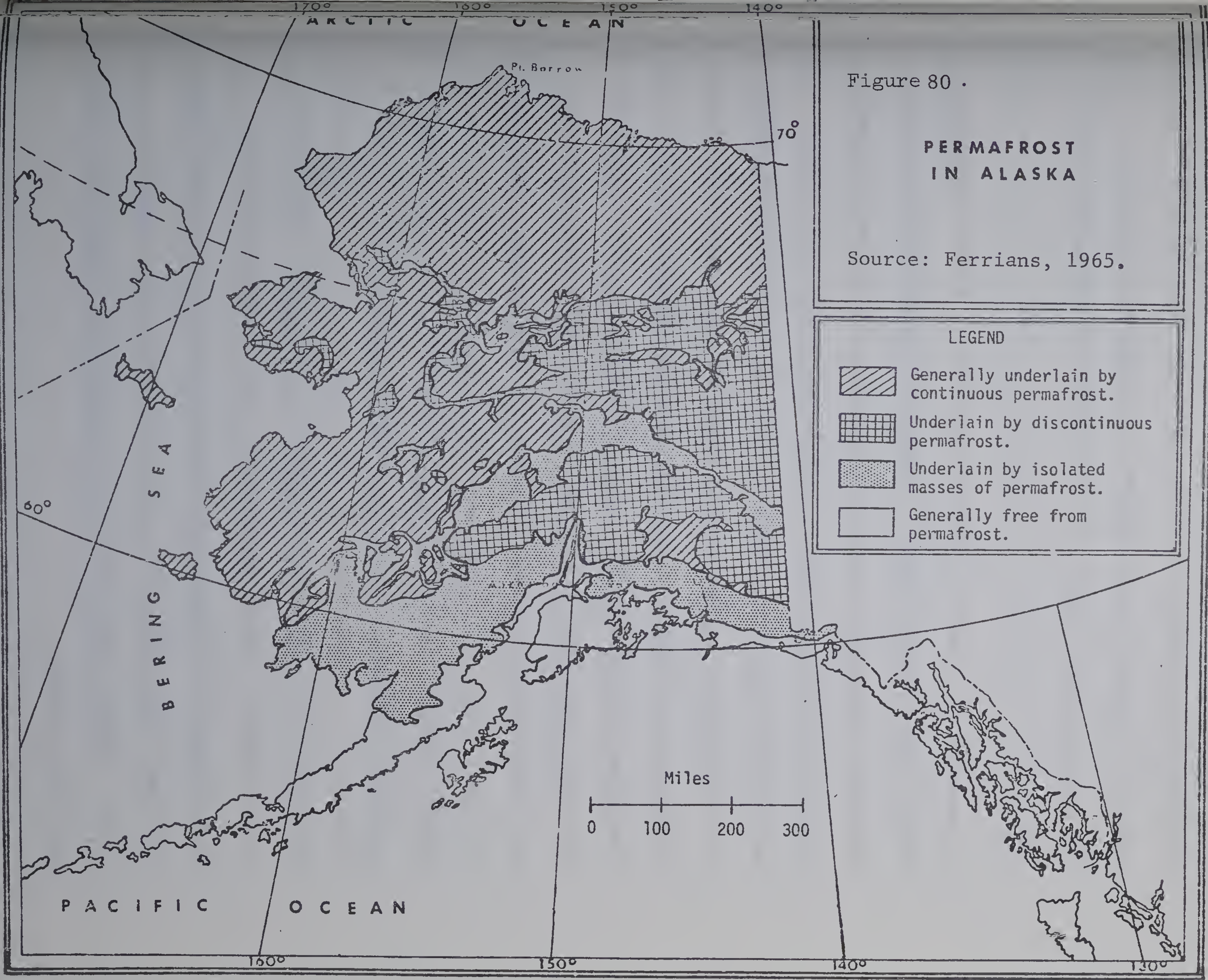


Figure 80.

PERMAFROST IN ALASKA

Source: Ferrians, 1965.

ARCTIC OCEAN
Pt. Barrow
170°
160°
150°
140°
70°
60°
130°
BERING SEA
PACIFIC OCEAN
LEGEND
▨ Generally underlain by continuous permafrost.
▦ Underlain by discontinuous permafrost.
░ Underlain by isolated masses of permafrost.
☐ Generally free from permafrost.
Miles
0
100
200
300

Most of the current permafrost in Alaska formed several thousand years ago during periods of extreme cold. Relict thicknesses exceeding 1000 feet are not uncommon; a maximum thickness of 2000 feet has been reported in the Prudhoe Bay area (Howitt and Clegg, 1970).

All permafrost regions in Alaska are subject to seasonal surface thawing. This "active zone" of summer melting generally deepens southwards ranging from 1/2 foot to greater than 5 feet, although physical conditions can induce considerable variations locally. Surface melting of the permafrost layer can increase the potential for solifluction--the downslope movement of water-saturated soils. In addition, successive freeze-thaw episodes characterized by incomplete refreezing within the active zone may isolate a water-laden thaw layer below the frozen surface. The rigid surface is then prone to frost-heaving, cracking and displacement. Artificial influences (e.g. structures, excavation, pipelines) which alter the surface thermal regime or drainage pattern can aggrevate these permafrost phenomenon and increase soil instability.

Knowledge of the extent and thickness of permafrost beneath the northern seas is largely speculative. The relatively few drill holes attempted in these areas revealed the top of the permafrost occurring from a few meters to over 100 meters below the sea bottom. However, these drilling operations have rarely penetrated the entire section.

Recent surveys of the Beaufort Sea have revealed the presence of "pingos", or relatively large mounds on the sea floor raised by frost action above the permafrost. These features, which occasionally come within 15 meters of the water surface, pose a potential hazard to deep-draft shipping, if undetected.

Earthquakes

The Gulf of Alaska-Aleutian Island Arc area is prone to frequent and occasionally severe earthquakes (Fig. 81). During the last 70 years, eight seismic events had recorded magnitudes that equalled or exceeded Richter 8 in that region. The most recent, the 1964 Prince William Sound (Good Friday) earthquake was recorded at Rickter 8.3-8.6. Exhaustive studies have been made on the effects of this quake. Among the more complete works are those by the National Academy of Sciences (1968-73) and the U.S. Geological Survey (1966-70).

Historically, the most severe earthquake damage has involved either structural failure caused by dynamic shaking or foundation failure resulting from ground rupture or loss of soil stability. Additional related phenomena include mass wasting (rock slides, mud slides, avalanches), differential settlement and seismic sea waves and seiches. Although severe damage during an earthquake is usually restricted within a 100 to 200 mile radius of the original epicenter, high intensity aftershocks can be initiated several

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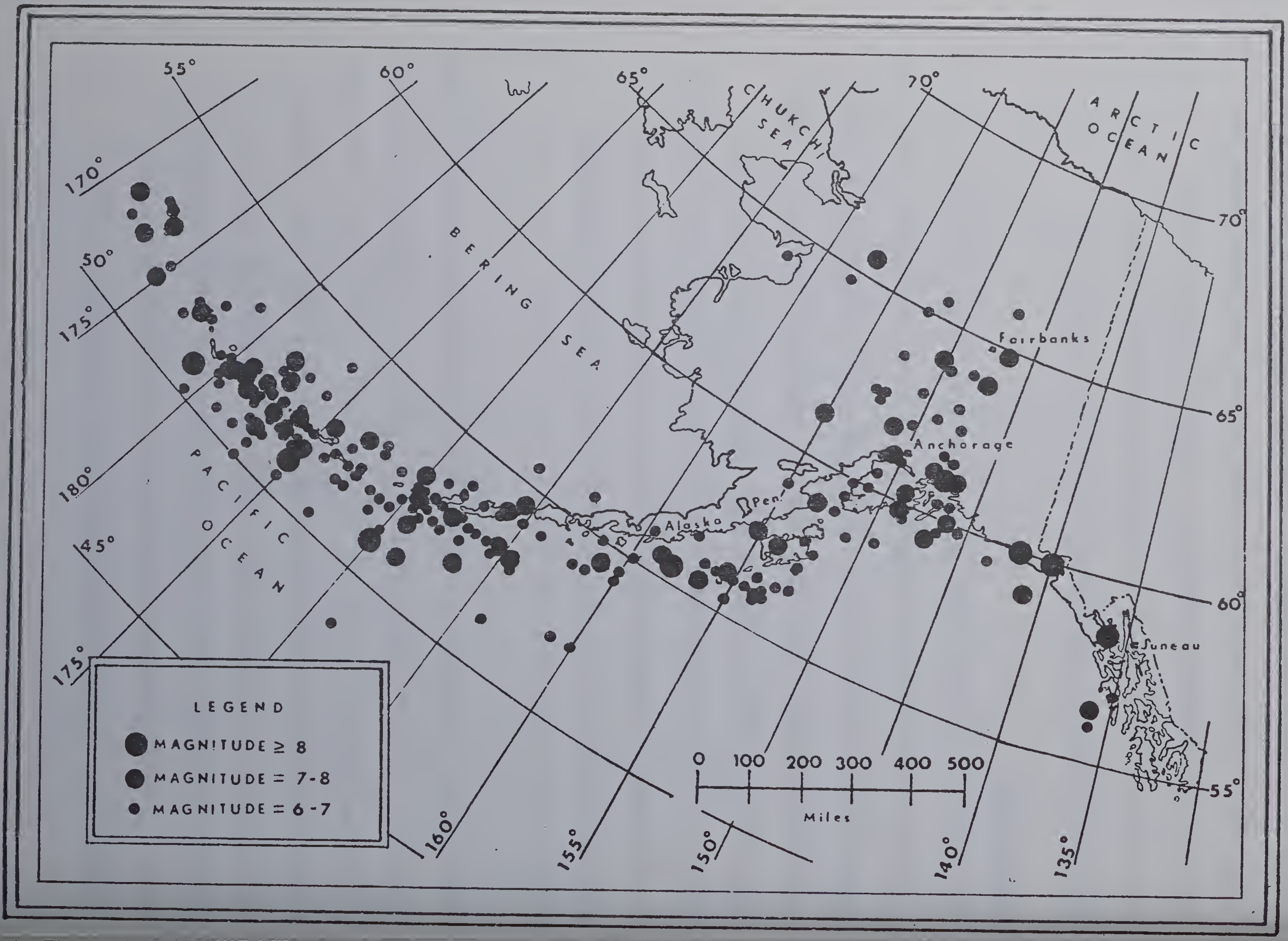


Figure 62. EARTHQUAKES IN ALASKA: MAGNITUDE ≥ 6, 1899 – 1964 FROM: U.S. COAST AND GEODETIC SURVEY, 1966

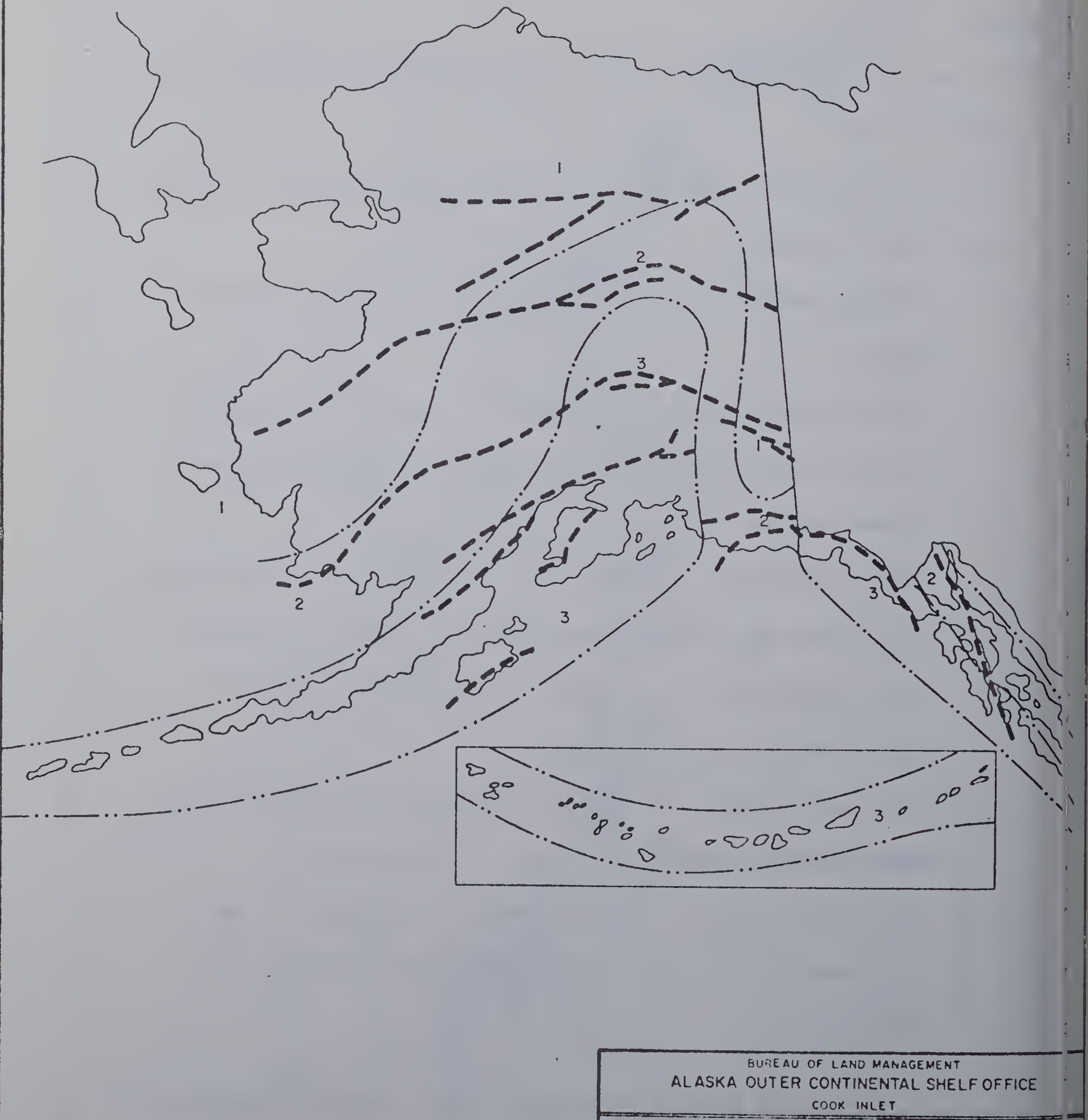
hundred miles along the active fault system. Figure 82 delineates zones of potential damage from seismic events within the State.

Faults

Swift et al. (1974) list the major fault systems in Alaska, from north to south, as:

1. Kaltag fault, extending from the southern side of Norton Sound to Tanana.
2. Tintina fault, bordering the south side of the Kandik Basin.
3. Denali fault system, extending in a hugh arc parallel to the south coast of Alaska from Bristol Bay past the Alaska Range.
4. Bruin Bay fault, bordering Lower Cook Inlet on the west and extending southwestward down the Alaskan Peninsula.
5. Castle Mountain fault, north of Anchorage, bordering the north side of Cook Inlet.
6. Fairweather fault, a north-northwestward trending fault that passes southwest of Juneau and Skagway.
7. The Chugach and St. Elias system that extends in an arc from Cordova into the Pacific Ocean southwest of Yakutat.

Major Alaskan faults are predominantly right-lateral, strike-slip faults, i.e. to an observer facing the fault, the opposing block



BUREAU OF LAND MANAGEMENT
ALASKA OUTER CONTINENTAL SHELF OFFICE
COOK INLET

Faults & Seismic Areas In Alaska

▬ ▬ ▬ Major Faults
—··— Seismic Zones
1-Minor structural damage(3.0-4.5)
2-Moderate structural damage(4.5-6.0)
3-Major structural damage(6.0-8.8)

Source Compiled in 1971 by the Federal Field Committee for Development Planning in Alaska from authoritative sources

Figure 82.

appears to have moved toward the right, parallel to the strike or surface expression of the fault.

The potential for significant activity along these fault systems increases in a southerly direction, towards the seismally-active areas of southern Alaska. Swift et al. (1974) caution that ". . .abundant active faults border the Gulf of Alaska, which, with the prevalence of earthquake epicenters and proximity to the Aleution Trench subduction zone make fault offset, with or without earthquake activity a significant hazard."

Volcanic Activity

The intense seismicity of the south Alaska coast is accompanied by active volcanism along much of the Alaskan Peninsula-Aleutian Island arc. The Aleutian Islands alone contain 76 major volcanos, about half of which have been active historically (Coats, 1950). Active volcanos are absent east of Cook Inlet and also along the western 600 miles of the Aleutian Island arc where the oceanic trench and related seismic events are less pronounced (Burk, 1965).

Volcanic eruptions in the Aleutian Island arc system tend to be more violent than those occurring within ocean basin areas, reflecting chemical differences in the materials involved. Physical phenomena commonly associated with these volcanic eruptions include:

explosive ejections of fine (ash) to coarse debris, lava flows, release of toxic and corrosive gases, volcanic earthquakes, and potential mud flows, corrosive rains, flash floods and abnormal sea waves. Hazardous effects of these events are normally limited to local onshore areas; their importance would diminish with increasing distance from shore.

(1) Gulf of Alaska

(a) General

The Alaskan Pacific-margin Tertiary basin is a 900 mile-long structural feature that roughly parallels the southern Alaska coast between Cross Sound and Chirkof Island. The basin covers an area of approximately 40,000 square miles (103,600 sq. km), mostly offshore, and is underlain by a thick section of Tertiary continental and marine strata varying in age from Paleocene through Pliocene. The basin sequence broadly includes a lower unit of well-indurated intensely-deformed early Tertiary rocks overlain by a less-altered section of mid to late Tertiary strata.

The Tertiary basin is subdivided into two geographic petroleum provinces, the Gulf of Alaska Tertiary province on the east and the Kodiak Tertiary province on the west. Although similar stratigraphically, these two areas display significantly different structural trends. The structural regime of the Gulf of Alaska province is characterized by east-trending features and

[redacted]

fault types that are similar to those found onshore, while the Kodiak province displays the regional N45°E structural trend and nearshore zone of high-angle faulting of the Aleutian structural system (von Heune, 1972). Figure 83 presents a generalized structural cross-section through the Kodiak Tertiary province.

(b) Hydrocarbon Potential

Since most of the known seeps and other indications of hydrocarbon are thought to have been formed in the mid to late Tertiary sedimentary sequence, Plafker (1971) suggests that these strata hold the best petroleum potential. Assuming an average thickness of 10,000-15,000 feet (3,048-4,572 meters) over an area of 25,000 square miles (64,750 sq. km), Plafker (1971) calculated that total volume of prospective Tertiary rock at 50,000-75,000 cubic miles (208,350-312,525 cu. km).

Tertiary strata within the Pacific-margin basin are bordered on the north and partially underlain by highly altered Cretaceous and other pre-Tertiary rocks that are considered to have no petroleum potential, but which may form an effective basement for more promising strata above.

The narrow continental shelf off southeastern Alaska is thought to be underlain by mainly non-prospective pre-Tertiary strata. Unmetamorphosed pre-Tertiary rocks which underlie the Hecata Island and Keku Islands areas, however, could contain petroleum (Gates et al., 1968).

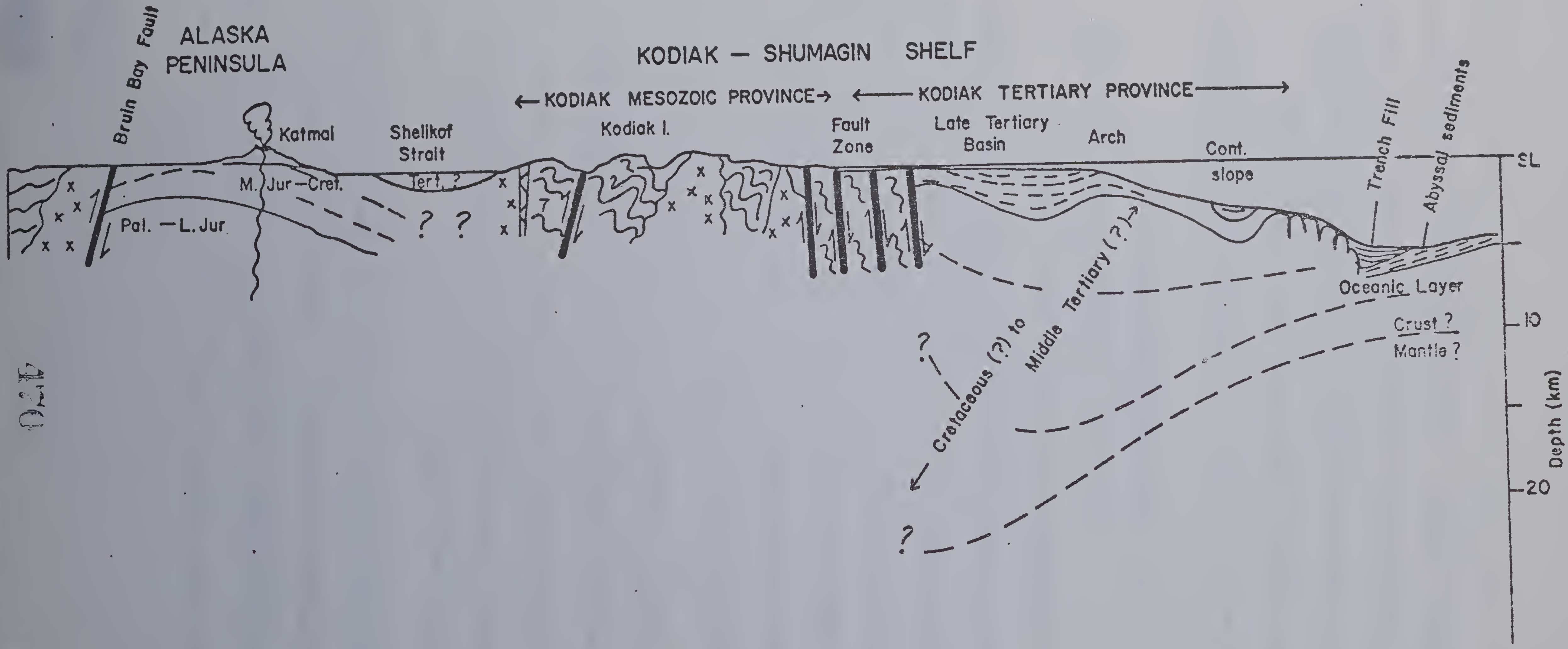


Figure 83. Generalized cross-section, Western Gulf of Alaska (from A.E.I. and D.C., 1974; after von Heune, et al., 1971 and von Heune, 1972).

(c) Geologic Hazards

The Gulf of Alaska OCS area is characterized by a great variety of potential geologic hazards, both onshore and offshore. As previously mentioned, the Western Gulf is seismically active and prone to frequent fault displacements. Figure 84, which shows regional effects of the 1964 Prince William Sound earthquake, is instructive in providing an estimate of the destructive influence of future high-magnitude earthquakes that may occur in the same area.

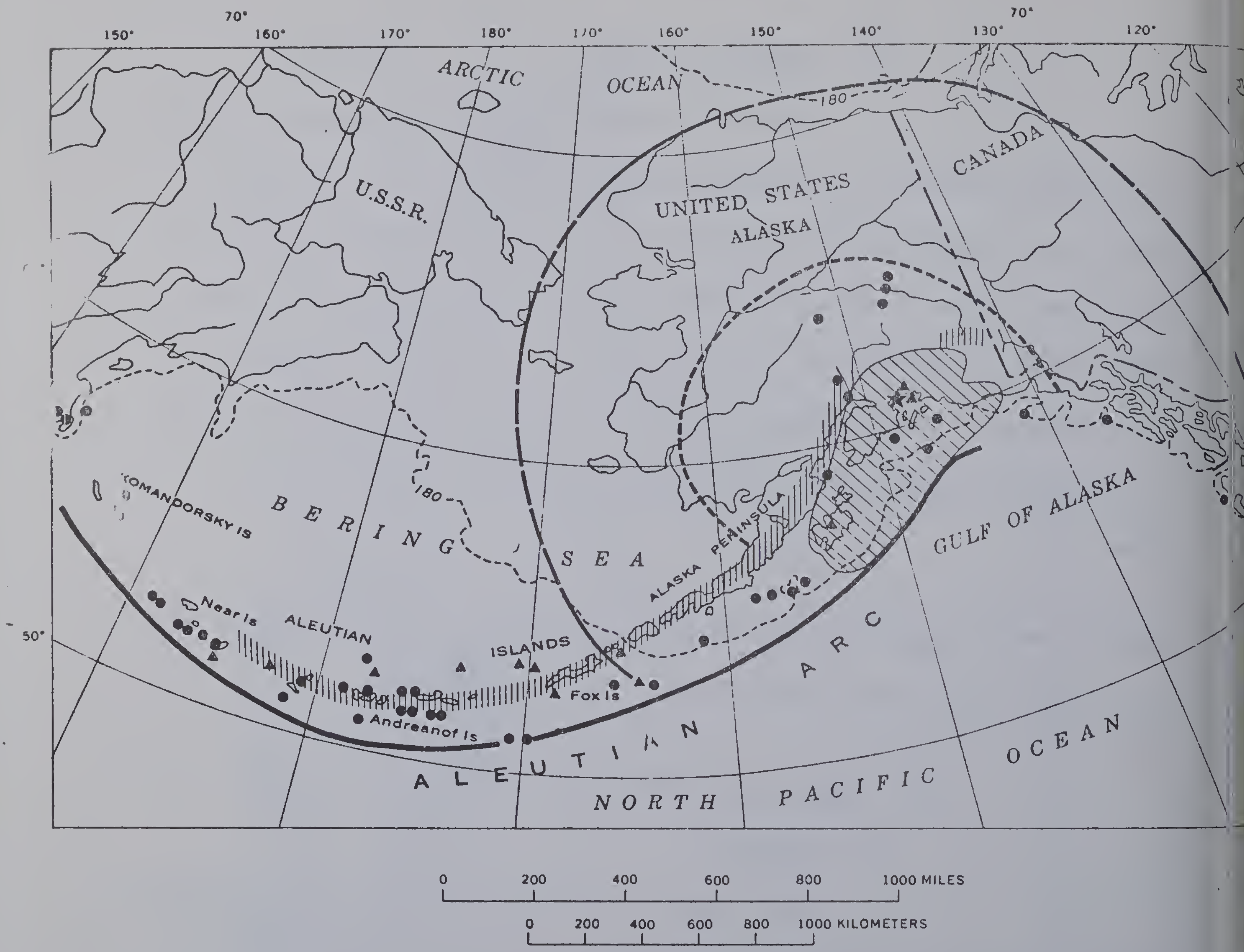
The extremely rugged northern Gulf coastline is extensive glaciated, with many of the ice flows extending to the shoreline.

(2) Lower Cook Inlet OCS

(a) General

Cook Inlet is an elongate, northwest=trending coastal embayment located in southcentral Alaska, just east of the Alaskan Peninsula. The Inlet measures roughly 230 miles in length and 85 miles in width. Water depths average generally less than 90 meters but increase southward to over 180 meters at the mouth of the estuary.

Bottom sediments are fine grained silt and clay representing the heavy sediment influx from rivers and streams, that drain the rugged, glaciated terrain surrounding the Inlet.



EXPLANATION

★
Epicenter of the 1964 earthquake

———— — —
Approximate limit of human perceptibility
Dashed where inferred

- - - - - - - - - - -
Approximate limit of landslides, avalanches, and ground cracks

▨
Approximate area of major tectonic deformation
Dashed where inferred

● Shallow depth (<70 km) ▲ Intermediate depth (70–200 km)
Large earthquake epicenters ($M > 7$) for period 1904-52
(From Gutenberg and Richter, 1954)

━━━━━━
Aleutian Trench

||||||||||||||||||||||||
Aleutian volcanic arc

- - - - - - - 180 - - - - - - -
Approximate outer edge of continental shelf
Depth in meters

Figure 84.

Map of Alaska and adjacent areas showing the location of the 1964 earthquake, the area affected by the eartl epicenters of previous major earthquakes, belts of active volcanism, and the Aleutian Trench.
(from Plafker, 1969).

Cook Inlet is both a topographic and structural basin that contains about 60,000 feet of Mesozoic and Cenozoic sedimentary rock. The older Mesozoic strata which crop out around the edge of the basin are primarily of non-marine origin while the thick younger Tertiary sequence is largely non-marine.

The basin is bounded by faults that parallel the general northerly structural grain of the region. Structural ridges within the basin are similarly aligned; many of these anticlines are associated with long, parallel reverse faults. All of the oil and some of the gas discovered in Cook Inlet has been in structural traps occurring along these trends (Fig.85a) (Crick, 1971).

(b) Hydrocarbon Potential

Cook Inlet basin represents the southern part of the 15,000 square mile (38,850 sq. km) Cook Inlet petroleum subprovince; also included is the Susitna Basin to the north (Fig.85b). About one-third of the Cook Inlet subprovince has been explored by drilling. The Lower Cook Inlet, covering an additional third of the total subprovince, is essentially unexplored. Available data indicates that the Lower Inlet has a thinner stratigraphic section with less structural potential than Upper Cook Inlet. Promising structures are present, however, and the erratic distribution of non-marine Tertiary strata within the sedimentary sequence

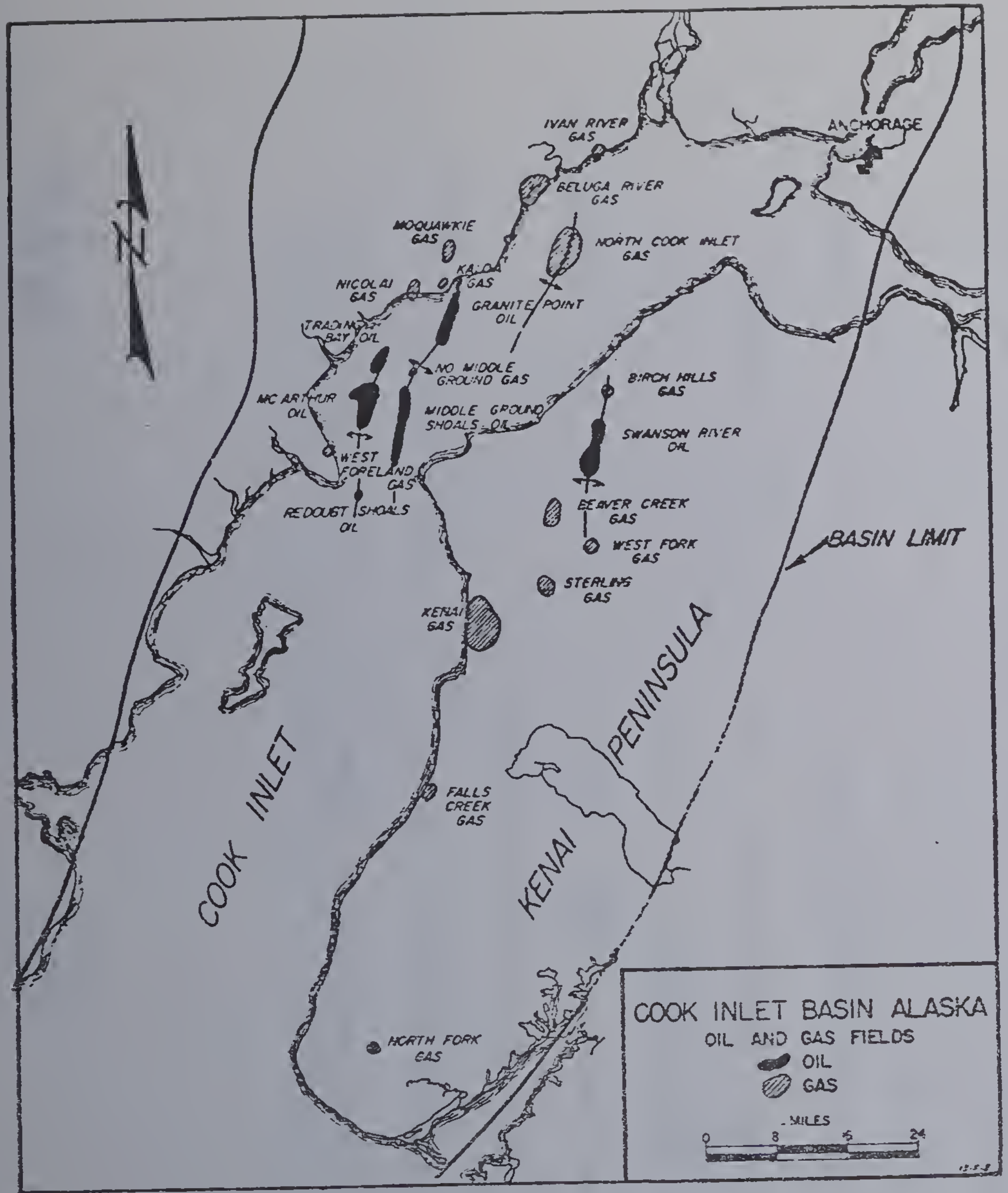


Fig. 85a.-Map of Cook Inlet basin showing structural trends and oil and gas fields.

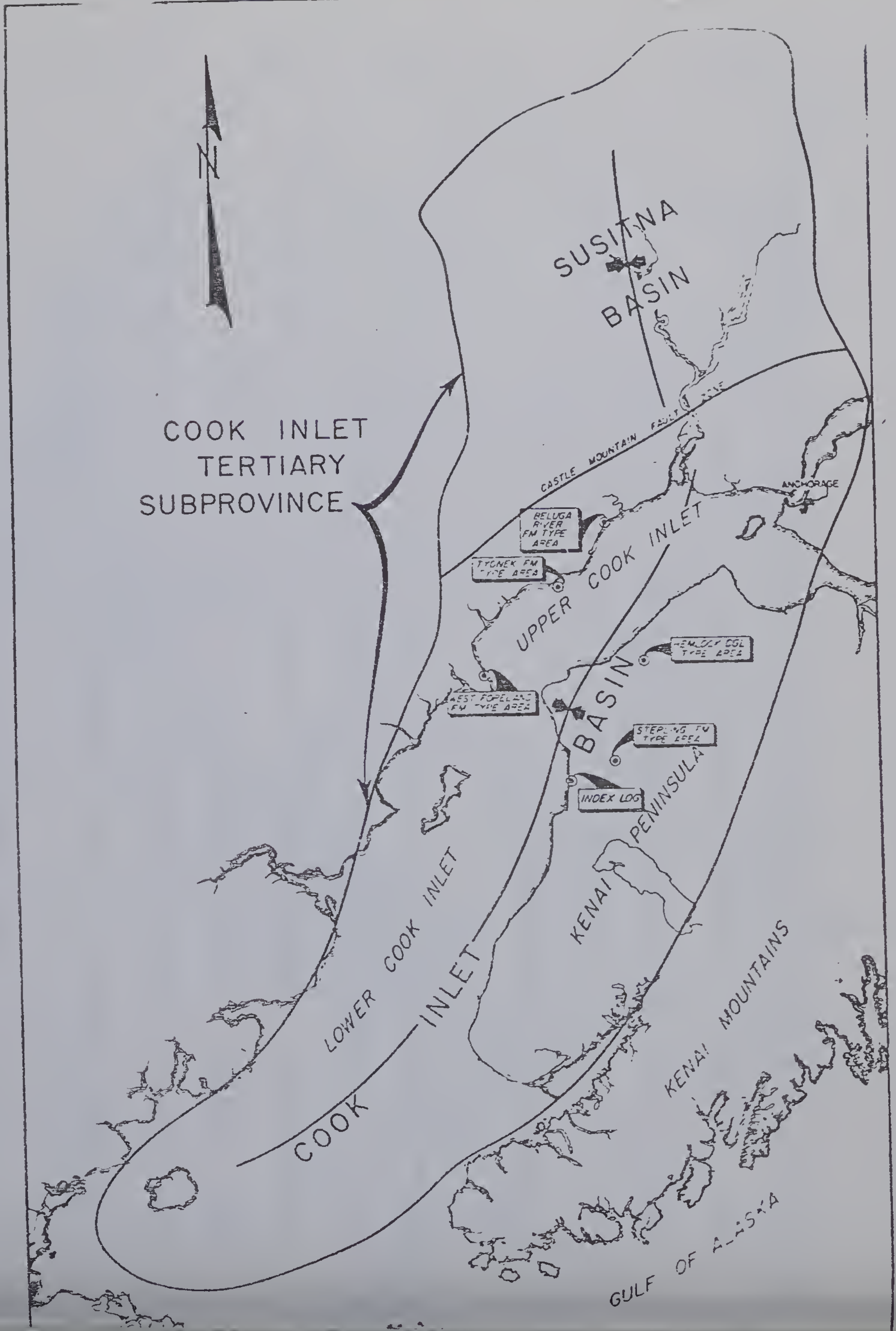


Fig. 85b.-Map of Cook Inlet Tertiary subprovince

Figure . (from Crick, 1971).

suggests that stratigraphic traps may also exist, throughout the basin. Potential for gas discoveries in Lower Cook Inlet should be good.

Crick (1971) estimated undiscovered hydrocarbon reserves of 7.9 billion bbl. of oil and 14.6 trillion cubic feet of gas exist in the total Cook Inlet petroleum subprovince. Table 72 gives a broad estimate of undiscovered hydrocarbon reserves for the Lower Cook Inlet OCS area.

(c) Geologic Hazards

Lower Cook Inlet lies within the seismically active zone of southern Alaska. At least 12 major earthquakes of magnitude greater than Richter 6 have occurred in the local area since 1899 (Fig. 86).

Although the eastern half of Cook Inlet is located within the zone of major tectonic deformation associated with the 1964 Prince William Sound earthquake, existing oil and gas wells in the area were not appreciably disturbed (Eckel, 1966). Fissured ground, mud and landslides, intense vibration, and ground movements were widespread, however, and can be expected to pose potential hazards to future offshore oil and gas development, during period of seismic activity.

Of the five volcanoes that occur in the vicinity of western Cook Inlet, three have erupted during the last 21 years. These

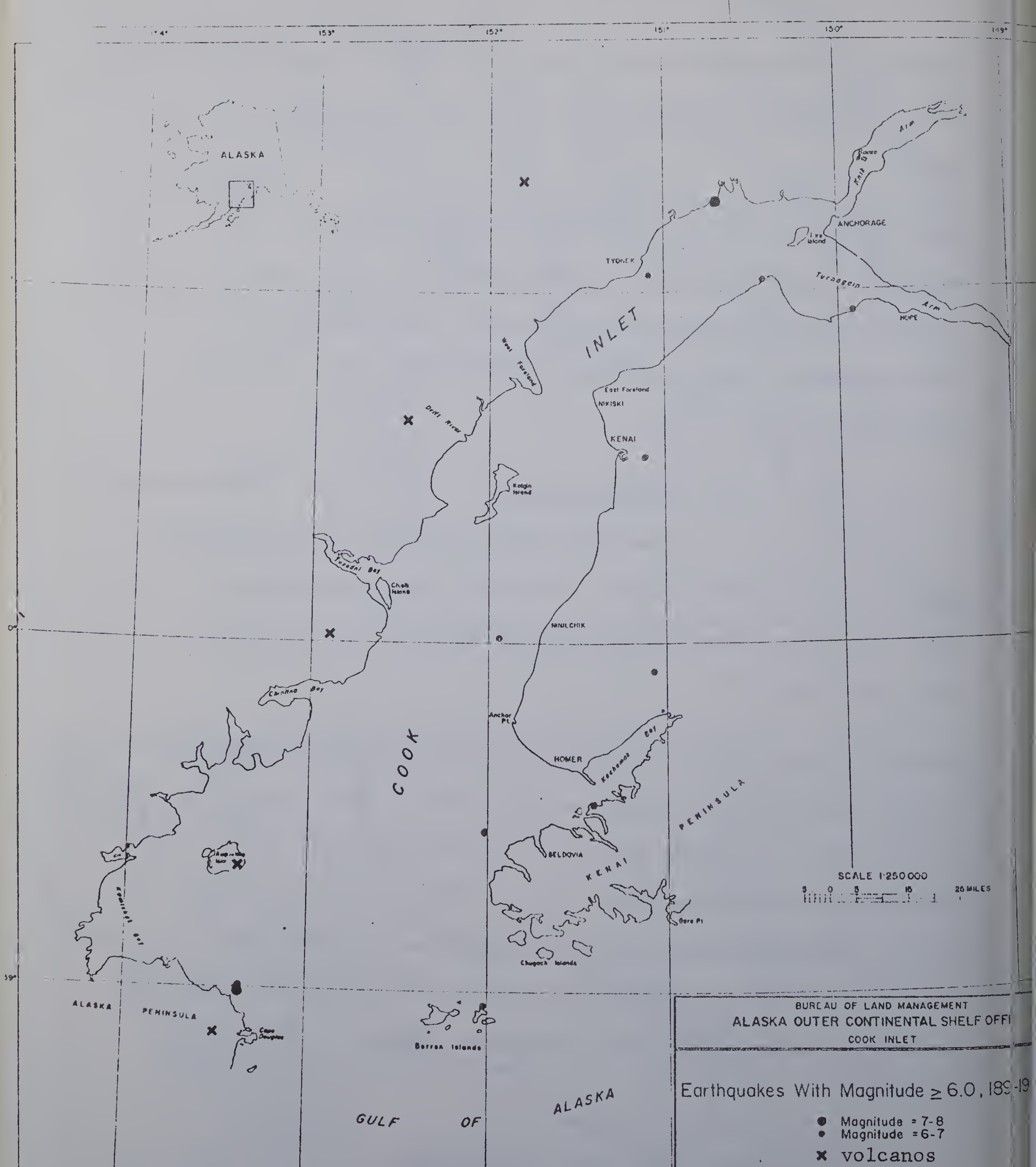

154°
153°
152°
151°
150°
149°
ALASKA
Knik Arm
ANCHORAGE
Fire Island
Turnagain Arm
HOPE
TYONEK
INLET
West Foreland
East Foreland
NIKISKI
KENAI
Drift River
Kalgin Island
Tuxedni Bay
Chisik Island
NINILCHIK
Chinitna Bay
Anchor Pt.
HOMER
Kachemak Bay
COOK
KENAI PENINSULA
SELDOVIA
Augustine Isl.
Kamishak Bay
ALASKA PENINSULA
Cape Douglas
Chugach Islands
Gore Pt
Barren Islands
GULF OF ALASKA
SCALE 1:250000
5 0 5 15 25 MILES
BUREAU OF LAND MANAGEMENT
ALASKA OUTER CONTINENTAL SHELF OFFI
COOK INLET
Earthquakes With Magnitude ≥ 6.0, 189-19
● Magnitude = 7-8
• Magnitude = 6-7
× volcanos
Source Fig. adapted from Evans al,

Figure 86.

eruptions have caused local damage from ash falls, sea waves, and flooding. Augustine Island, an active volcano located in southwestern Cook Inlet, represents the most immediate volcanic hazard to future oil and gas operations within the Lower Inlet.

(3) Southern Aleutian Shelf OCS

(a) General

The Southern Aleutian Shelf forms a narrow arcuate zone that is sandwiched between the Aleutian Islands-Alaskan Peninsula on the north and the Aleutian Trench on the south. Width of the shelf varies from less than 50 miles (80 km) west of Unimak Island to about 150 miles (240 km) in the east, near Kodiak Island. The main shelf area is characterized by the presence of broad plateau-like areas dissected by relict glacial drainage channels. Regional slope gradients are generally less than 0°5'. The shelf break is very distinct and occurs in water depths from 120-130 meters off Unimak Island to 150-160 meters off Kodiak Island.

Shelikoff Strait, separating Kodiak Island from the Alaskan Peninsula, represents the best-defined of a series of broad, flat-bottomed submarine valleys that parallel or sub-parallel the mainland coast, and are thought to relate to the current tectonic regime of the area.

Beyond the continental shelf, a steep, rugged continental slope drops more than 5,000 meters to the Aleutian trench over a horizontal distance of 30 to 80 km. Von Huene (1972) characterized the slope topography as a relatively smooth upper section, a bench-like middle section and a steep, irregular lower section. The bench areas apparently signify large-scale slumping.

Structural elements of the Southern Aleutian Shelf follow the N45°E trend of the Aleutian structural system.

(b) Hydrocarbon Potential

Tertiary sedimentary rocks of the Kodiak Tertiary petroleum province extend westward beneath the South Aleutian Shelf OCS area to the vicinity of Chirikof Island. The petroleum potential of this province was discussed previously as part of the Pacific Margin Tertiary Basin (see section IIA4a(1)(b)) Although seismic data covering the western shelf is available, insufficient faunal and lithologic information exists to allow a meaningful evaluation of resource potential.

(c) Geologic Hazards

Much of the seismic activity associated with island arcs is confined to the zone which separates the active volcanic island chain from the oceanic trench. Since the Southern Aleutian Shelf occupies that area of the Aleutian Island Arc system, seismic risk is accordingly high. In addition, volcanic hazards, discussed previously, are evident in all but the westernmost part of the island chain.

[redacted]

(4) Bristol Bay OCS

(a) General

The Bristol Bay OCS area falls within the large Bristol Bay basin, a structural and sedimentary trough bounded by the Alaska Peninsula arch and the related Bruin Bay fault on the southeast, and by the Goodnews Arch and its seaward projection on the northwest. Exposures of highly-deformed, locally intruded Paleozoic and Mesozoic rocks delineate the northeastern margin of the basin while its southeastern extension terminates with the continental slope (Fig.87a). Limited seismic and drilling data suggest a three-fold geologic division of the Bristol Bay basin, with regard to the nature of effective basement which underlies potential oil-bearing strata (Hatten, 1971). In the northeast subprovince, Tertiary strata lie on an irregular basement surface of pre-Tertiary volcanic and metamorphic rocks. To the southwest, between Ugashik Bay and Port Moller, the effective basement consists of younger mid-Tertiary volcanics. The third geologic subprovince, extending southwest of Port Moller to the edge of the continental margin, contains a very thick section of structurally-complex, alternating marine and non-marine Mesozoic strata. Seismic profiles have failed to reveal a distinct basement surface in this area (Fig. 87b).

The northeast region of the Bristol Bay basin contains from 2000 feet to 16,000 feet (610-4880 m) of non-marine and shallow water marine

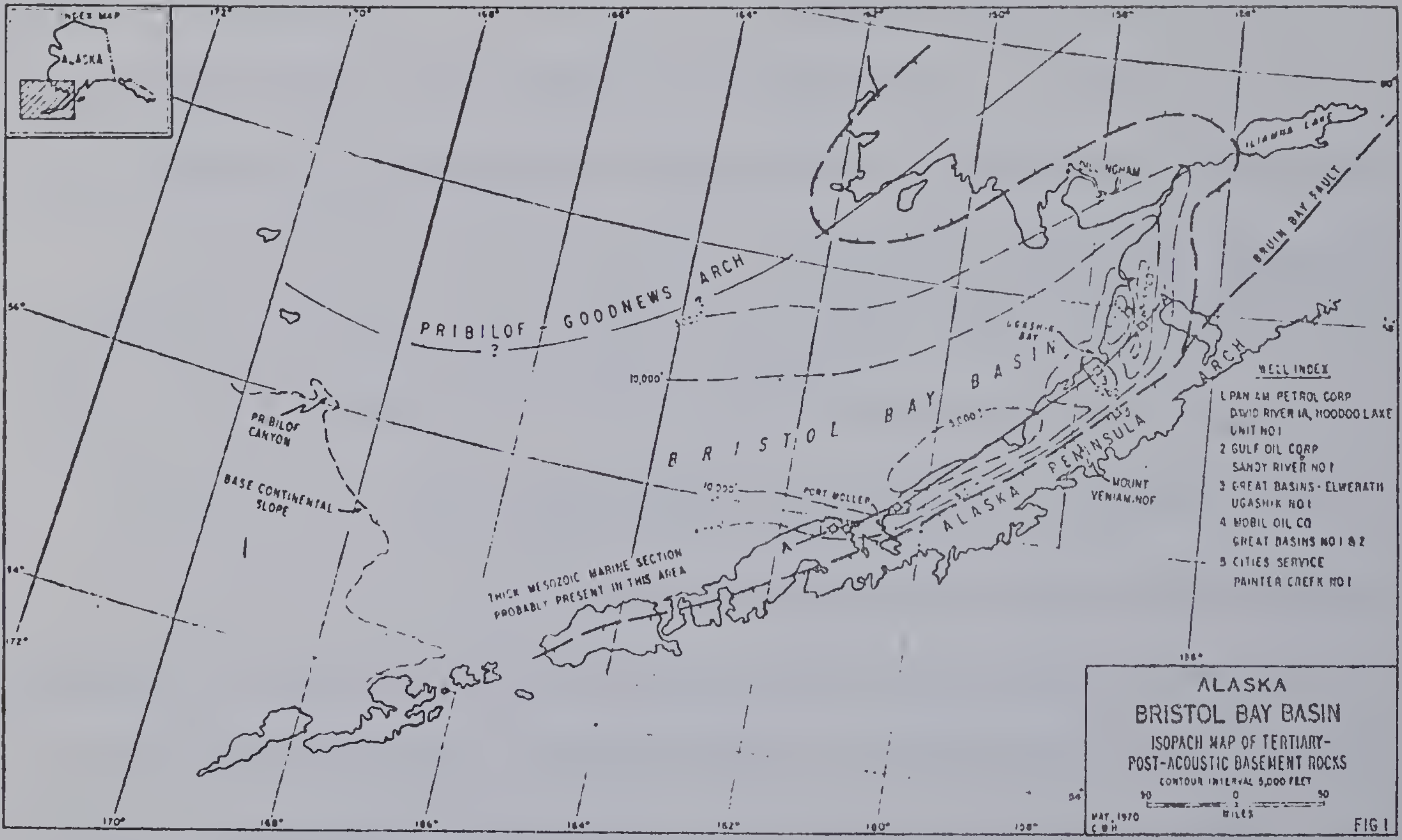

INDEX MAP
ALASKA
PRIBILOF - GOODNEWS ARCH
BRISTOL BAY BASIN
10,000'
5,000'
PRIBILOF CANYON
BASE CONTINENTAL SLOPE
THICK MESOZOIC MARINE SECTION PROBABLY PRESENT IN THIS AREA
PORT MOLLER
ALASKA PENINSULA
ARCH
MOUNT VENIAMINOF
ILIAMNA LAKE
BRUIN BAY FAULT
WELL INDEX
1 PAN AM PETROL CORP DAVID RIVER IA, HOODOO LAKE UNIT NO 1
2 GULF OIL CORP SANDY RIVER NO 1
3 GREAT BASINS - ELWERATH UGASHIK NO 1
4 MOBIL OIL CO GREAT BASINS NO 1 & 2
5 CITIES SERVICE PAINTER CREEK NO 1
ALASKA
BRISTOL BAY BASIN
ISOPACH MAP OF TERTIARY-POST-ACOUSTIC BASEMENT ROCKS
CONTOUR INTERVAL 5,000 FEET
50 0 50
MILES
MAY, 1970
FIG 1
170°
168°
166°
164°
162°
160°
158°
156°
54°
56°

FIG. 87a

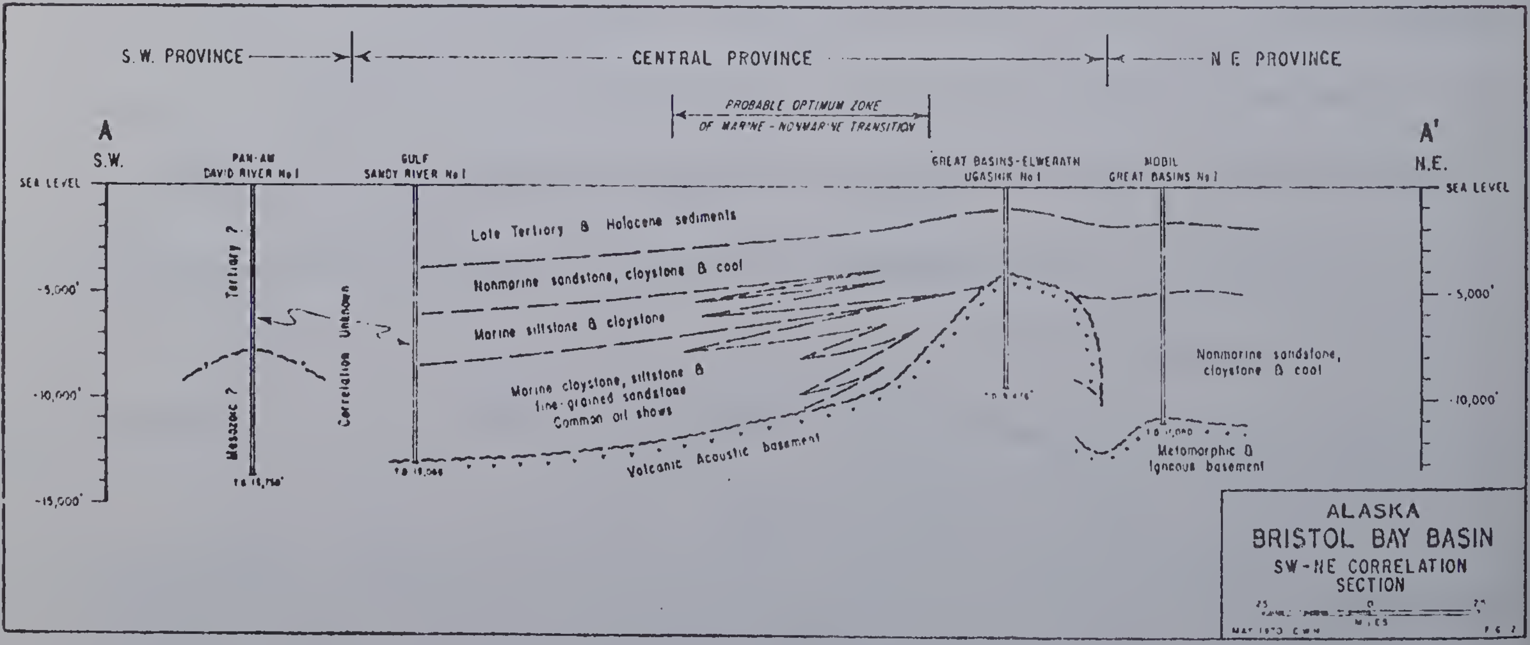

S.W. PROVINCE
CENTRAL PROVINCE
N E PROVINCE
PROBABLE OPTIMUM ZONE OF MARINE - NONMARINE TRANSITION
A
S.W.
A'
N.E.
SEA LEVEL
-5,000'
-10,000'
-15,000'
PAN-AM DAVID RIVER No 1
GULF SANDY RIVER No 1
GREAT BASINS-ELWERATH UGASHIK No 1
MOBIL GREAT BASINS No 1
Tertiary ?
Mesozoic ?
Correlation Unknown
Late Tertiary & Holocene sediments
Nonmarine sandstone, claystone & coal
Marine siltstone & claystone
Marine claystone, siltstone & fine-grained sandstone Common oil shows
Volcanic Acoustic basement
Nonmarine sandstone, claystone & coal
Metamorphic & Igneous basement
ALASKA
BRISTOL BAY BASIN
SW-NE CORRELATION SECTION
MILES

FIG. 87b

Figure 87. (from Hatten, 1971).

[redacted]

Tertiary rocks. The central province is distinguished stratigraphically by a thin eastern non-marine sequence that thickens southwestward to over 12,000 feet (3660 m) while assuming a more marine character.

Structural deformation in the sedimentary sequence of the Bristol Bay basin is most pronounced along the northwest flank of the Alaska Peninsula arch. Extensive faulting has also occurred in the volcanic basement of the central Bristol Bay basin, however these features do not appear to extend into the overlying beds. Mesozoic strata to the southwest have been faulted and broadly folded out to the edge of the continental slope, while the overlying Tertiary section is only mildly deformed (Scholl and Hopkins, 1969).

(b) Hydrocarbon Potential

Hatten (1971), summarizing a discussion of the petroleum potential of the Bristol Bay basin, concluded: "Large commercial quantities of hydrocarbons can be anticipated in structural and stratigraphic traps within a wide belt of transition between a marine Tertiary section in the southwest part of the basin and a non-marine Tertiary section in the northeast. Other accumulations may be found in the marine Mesozoic rocks of the southwest. . . ."

An estimated 1 to 2 million acres of the Bristol Bay OCS region have petroleum potential.. See Table 72 for resource estimates.

(c) Geologic Hazards (See also Sec. II.A.4.a. Intro.)

Potential geologic hazards in the Bristol Bay region do not appear to be severe and involve primarily seismicity and permafrost. The area is relatively close to the seismically-active Aleutian arc and fall mostly within seismic risk zone 2, signifying moderate potential structural damage (see Fig.82). Sporadic volcanic activity along the southern coastal areas exerts a local influence. To the north, the onshore Denali fault system probably extends offshore, however this system has not shown appreciable activity in recent times (Swift, et al., 1974).

Isolated patches of permafrost occur at highly variable depths throughout the northern onshore regions of Bristol Bay (Ferrians, 1965). The nature and distribution of offshore permafrost, however is not currently known.

(5) Bering Sea OCS

(a) General

The Bering Sea represents a large (890,000 sq. mi. [2.3 million km^2]), relatively confined extension of the North Pacific Ocean. It is bounded by the northerly-convergent coastlines of Alaska and Siberia on the east and west, respectively, and the Alaskan Peninsula/Aleutian Island arc on the south. A narrow passage, the Bering Strait, opens into the Chukchi Sea to the north.

Nearly half of the total Bering Sea is underlain by a relatively smooth continental shelf which forms the southern portion of the expansive Bering-Chukchi Platform. The Bering Shelf segment is widest along the eastern and northern coasts, extending offshore over 400 miles in some places. It swings northwest near Unimak Island, then narrows considerably along the Kamchatka Peninsula to enclose the Aleutian (Bering Sea) Basin. An arcuate submarine ridge (North Rat Island Ridge) extends northwest from the central Aleutian Islands into the basin, while another submarine feature, the Olyutorski Ridge, penetrates the abyss from the northeast near Kamchatka. Water depths over the Alaskan Bering Sea shelf average about 55 meters. The virtually flat shelf terminates abruptly seawards at about 160 meters water depth, giving way to one of the steepest known continental slopes. At average declivities that commonly exceed 20° (Dietz, et al., 1964), the irregular slope drops quickly from the shelf break to the 3800-3900 meter depths of the Bering Sea basin.

Several islands surface above the Bering Sea shelf. Many of these islands represent thick accumulations of volcanic flows and debris interspersed with some sedimentary strata.

Acoustic reflection records reveal a generally thin cover of Holocene sediments overlying the southeast Bering Sea shelf. While varying from 0 to 10 meters, sediment thickness averaged 3 meters (Moore, 1964) in this area. The unconsolidated Holocene sediment cover over the northeast Bering Sea shelf is similarly thin, but more variable in thickness. Local areas of relatively thick (up to 30 meters) deposits were found near St. Matthews and the Pribilof Islands (Moore, 1964). Figure 88 depicits the distribution of unconsolidated sediments on the northeastern Bering Sea shelf. Fine sand is shown to be the predominant sediment type in the area in contrast to the generally finer-grained bottom constituents of the Chukchi Sea to the north.

Most of the Holocene sedimentation along the eastern Bering shelf has apparently occurred at the delta fronts of major coastal rivers, with relatively little redistribution of material across the shelf.

The Bering Sea OCS area contains several sedimentary and structural basins that have served as centers of Cenozoic deposition. The Norten Basin, covers an area of about 38,600 square miles (100,000

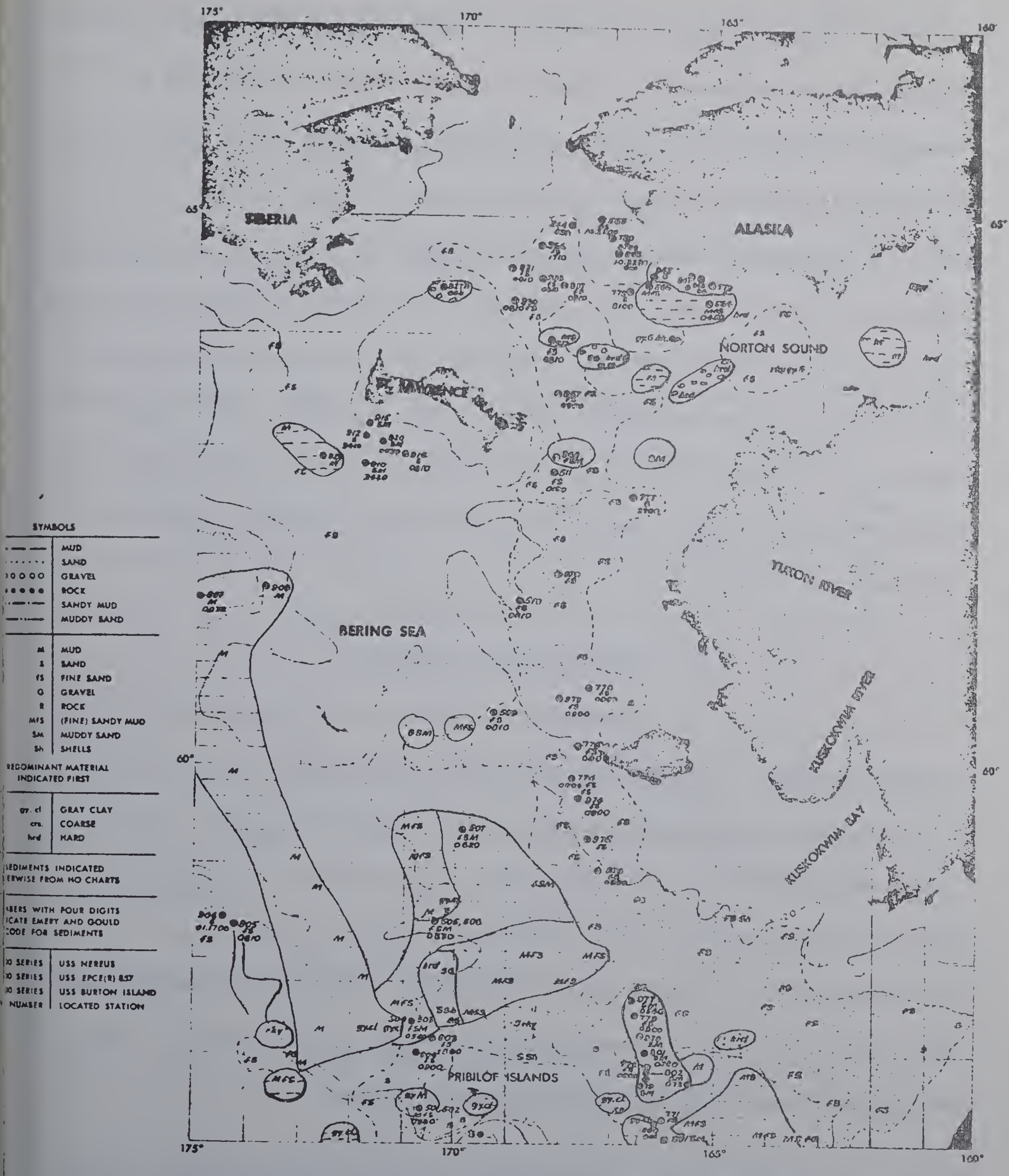


Figure 88. Bering Sea shelf sediments (from Dietz, et al., 1964).

sq. km) extending from the shores of Norton Sound westward to Cape Chukotsky and between the Seward Peninsula on the north and St. Lawrence Island to the south. The basin contains up to 6600 feet (2000 m) of marine and non-marine Cenozoic strata similar to the Bristol Bay basin sequence to the southeast. Pribilof, St. George, Zhemchum, Navarin, and other similar but unnamed basins are elongate outer-shelf basins of broadly deformed and faulted marine deposits which parallel the northwest trend of the adjacent shelf margin. Whereas the inner-shelf Norton and Bering Sea basins represent large structural sags, many of the outer-shelf basins appear to be fault controlled.

(b) Hydrocarbon Potential

Petroleum prospects of the Bering Sea OCS region include: (1) the thick sections (basins) of Cenozoic and, in some areas, Cretaceous strata underlying broad areas of the continental shelf, (2) deformed Mesozoic rocks which underlie many of these basins, (3) domical and diapiric structures associated with the more deeply submerged (2000 m) Umnak Plateau area, and (4) thick masses of late Tertiary beds in summit basins along the crestal region of the Aleutian Ridge.

The most promising prospects are the thick accumulations of early Tertiary through Holocene beds that occur in the larger inner-shelf basins which underlie the shelf's major bays and gulfs (Norton and Bristol basins).

Many of the outer-shelf basins, however, are underlain by folded Cretaceous and Jurassic strata which are not only prospective in themselves, but may have supplied hydrocarbons to overlying Cenozoic structures.

Other promising areas are the fairly large (as much as 30 x 80 km) summit basins of the 2200 km-long Aleutian Ridge. Roughly rectangular in shape and elongate parallel to the ridge, these structures are physiographic as well as geologic basins. The floors of two of them, neighboring Amukta (171.7°W) and Amlia (173°W) Basins, lie at a water depth of about 1000 meters and are underlain by a 3 to 4 km. thick late Tertiary sedimentary section. These basins are bordered by major normal faults. The infilled section is broadly folded as well as disrupted along high-angle growth faults.

See Table 72 for resource estimates.

(c) Geologic Hazards

Potential geologic hazards in the Bering Sea OCS area are not severe. Seismic activity is minimal (zone 1) in all but the southernmost area, unconsolidated sediment cover is generally thin, and known faults are fairly inactive. The nature and distribution of offshore permafrost are unknown, although patchy to continuous occurrences of highly variable relict thickness are most likely present in the mid to northern shelf areas.

(6) Chukchi Sea CCS

(a) General

The Chukchi Sea, off the Alaskan arctic coast, extends northward between Wrangel Island and Point Barrow to the edge of the continental shelf (Fig. 89). The underlying Chukchi Bering-Chukchi platform which joins the Asian and North American continents. Water depths over the greater part of the shelf are generally less than 55 meters, with 40 meters depths commonly occurring 50 to 100 km off the Alaskan coast. Kotzebue Sound, a large, shallow coastal bay, dominates the southeastern Chukchi shoreline.

The Chukchi continental shelf is generally smooth, although Carsola (1954) characterized its outer margin as an area of minor topographic roughness. A broad topographic high shoals at 13 meters north of Bering Strait at about 70°30'N (Dietz, et al., 1964). To the west, a submarine canyon, Herald Canyon, extends northward along 173°W longitude to the outer continental margin. Beyond the shelf, the continental slope descends from 65m to about 180m water depth. A 100 mile-wide continental rise segment completes the continental margin sequence.

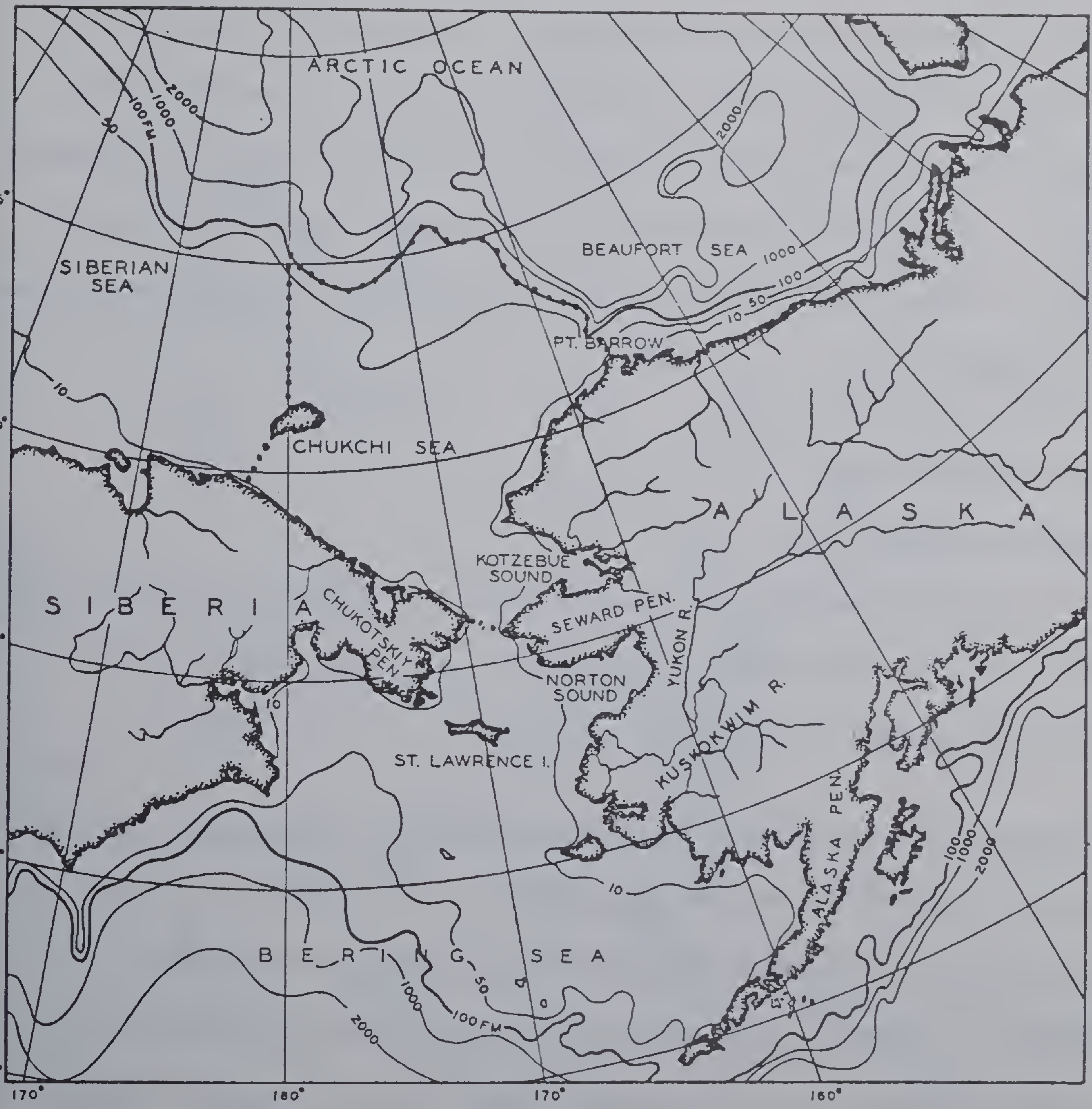


Figure 89. Bering-Chukchi Platform; dotted outline delineates Chukchi Sea boundary (after Moore, 1964).

Ice activity has resulted in a patchy distribution of sediment types on the Chukchi Sea shelf (Fig. 90). Most of the shelf is coated with a veneer of unconsolidated mud, sand and gravel derived from the mixing of poorly-sorted ice rafted debris with normal shelf sediments. Thicker deposits of fine grained river-derived sediment have accumulated in the Kotzebue Sound, while along the adjacent Bering Strait, swift-moving currents have removed the unconsolidated sediment cover.

Subsurface Geology

Northern Chukchi Sea

A subsurface structural ridge, the Barrow arch, arcs northwest from Point Barrow, then southwest across the northern Chukchi Sea dividing it into two distinct terranes.

A southward-thickening Mississippian-Jurassic sedimentary section extends between the Barrow arch and the north foothills of the Brooks Range and its offshore extension. These older strata are overlain by organic-rich early Cretaceous shales that are thought to have provided the oil trapped in the Prudhoe Bay field. Above these shale beds, younger Cretaceous strata contain a major resource of sub-bituminous and bituminous coal and at least some oil and gas on the North Slope of the Brooks Range. They and older rocks are bounded on the south by a major thrust fault zone.

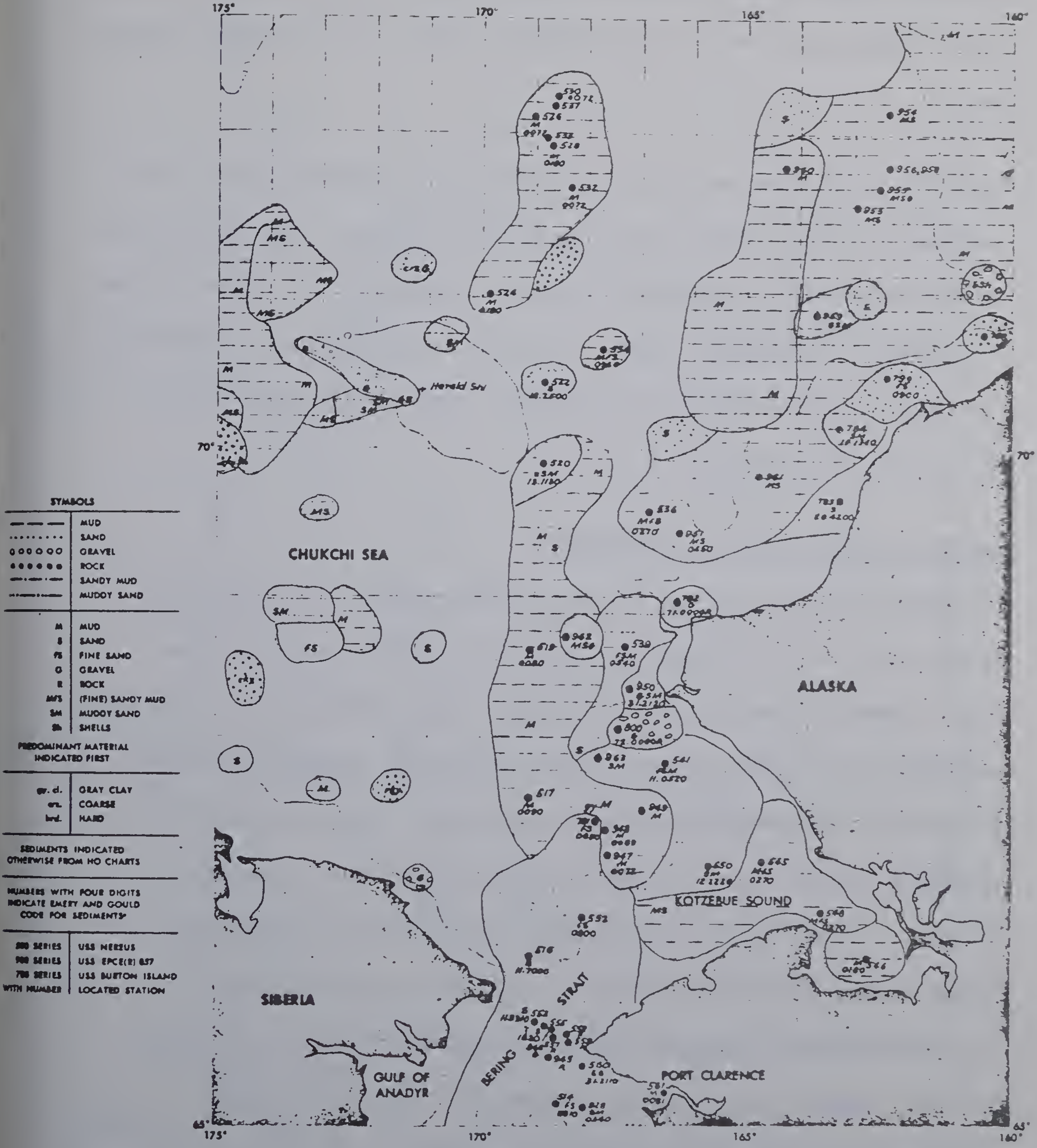


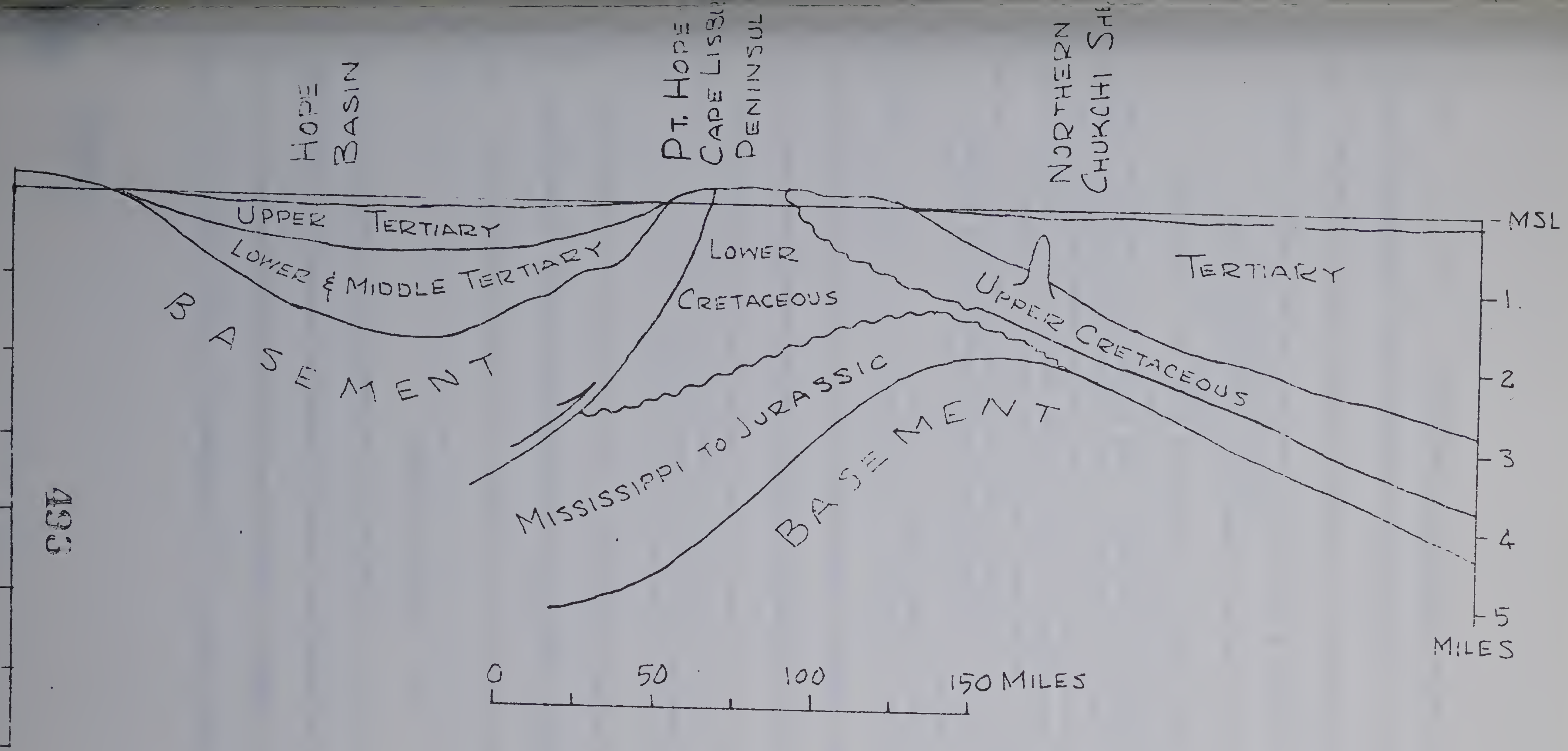
Figure 90. Chukchi Sea shelf sediments. (from Dietz, et al., 1964).

Wrinkled carpet folds related to these faults dominate the structure of the Cretaceous beds in the southern part of the northern Chukchi Sea.

North of the Barrow arch, a thick sequence of bedded rocks dips northward from the arch to the continental slope. The upper beds in this sequence, presumably Tertiary in age, overlie older rocks of probable Cretaceous origin. Several large diapirs, extend into the Cretaceous-Tertiary sequence; some pierce the entire section to the sea floor.

Southern Chukchi Sea -- Hope Basin

The Hope Basin is a broad structural depression that underlies a large portion of the Chukchi Sea south of 69°N latitude. The basin formed in early or mid-Tertiary time across a broad terrain underlain by locally altered and structurally complex Paleozoic to Mesozoic sedimentary and volcanic rocks. The basin fill is probably entirely clastic and of mixed marine and non-marine origin. A lower Tertiary sequence up to 5000 feet thick was later mildly faulted and folded. Subsequent deposition of a Plio-Pleistocene sequence reached a maximum thickness of about one km. Figure 91 represents a schematic N-S stratigraphic cross-section through the Chukchi Sea OCS.



SCHEMATIC CROSS SECTION OF NORTH & SOUTH CHUKCHI SEA

Figure 91

Source: U.S. Geological Survey

(b) Hydrocarbon Potential

The northern Chukchi Sea is underlain by some of the same geological features which co-joined to produce the super-giant oil and gas field at Prudhoe Bay and several lesser oil and gas fields in and near Naval Petroleum Reserve No. 4. Sedimentary deposits north of the Barrow arch may well attain thicknesses of 20,000 feet or more. The possibility that they may represent a late Cretaceous and Tertiary delta, combined with the presence of diapiric structures, makes the area attractive for petroleum exploration. The polar ice pack, however, may prevent adequate exploration for many years to come.

The presence of a regional arch, many smaller folds and numerous faults in the older sedimentary sequence, combined with a local erosional surface at the base of the younger sequence offer good oil and/or gas trapping potential within the Hope Basin.

There are an estimated 58 million acres with petroleum potential within the northern Chukchi Sea OCS and approximately 16 million acres in the Hope Basin. See Table 72 for resource estimates.

(c) Geologic Hazards

Although much of the Chukchi Sea OCS has not been surveyed, potential geologic hazards related to seismicity, bottom sediment stability, shallow subsurface conditions and submarine topography appear to be minimal.

Bottom scour by sea ice along northern coastal areas will affect pipeline placement, A relatively thick permafrost-active zone may exist within some offshore regions.

(7) Beaufort Sea OCS

(a) General

Spanning the Alaskan-Canadian northern coastal boundary, the Beaufort Sea is properly treated as an integral part of the larger Arctic Ocean. Traditional boundaries, however, include Banks Island in the Canadian Arctic Archipeligo on the east and the Chukchi Sea (156°30'W) on the west. A northern boundary has been arbitrarily defined by the International Hydrographic Bureau (Sp. Pap. 23, 1953) as the line joining Point Barrow and Cape Lands End (Prince Patrick Is.).

The Beaufort Sea shelf off Alaska is relatively narrow, varying in width from about 60 miles (97 km) in the west to approximately 30 miles (48 km) in the east. The shelf break lies between 50 and 70 meters water depth. Several submarine valleys dissect the shelf. The largest, Barrow Sea Valley trending northeastward off Point Barrow, extends across the shelf into the Arctic Ocean Basin.

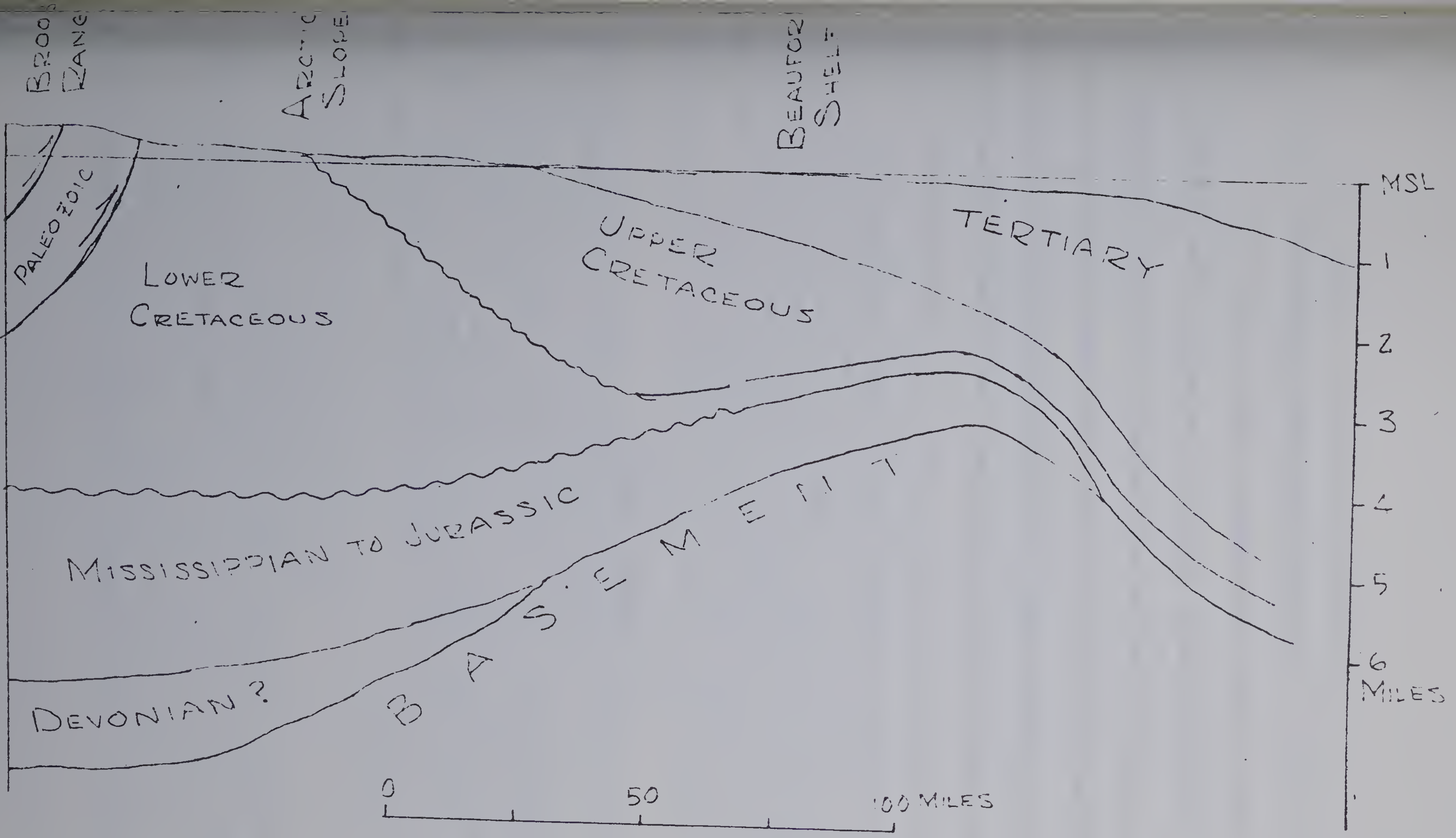
Surface sediments on the Beaufort Sea shelf are similar to those described in the northern Chukchi Sea--a poorly-sorted mixture of mud, silt, sand and gravel. Gravel content is highest along the shelf outer margin (Rodeick, 1974).

[redacted]

The seasonal input of sediment from coastal rivers complements shoreline erosional processes as the major sources of new sediment supplied to the Beaufort shelf. Much of this material enters the longshore drift regime and is slowly transported westward as part of the shifting system of sand bars and barrier islands that parallel the Beaufort coast. A similar, but eastward-flowing littoral drift occurs to the west of Point Barrow. Rex (1964) suggests that Barrow Sea Valley may provide the main channel for removal of the littoral sediment supplied to the Barrow area by the coverging coastal currents.

Subsurface Geology

The Beaufort shelf and slope is underlain by a progradational sequence of Cretaceous marine and some non-marine sedimentary rocks that dips northward off the Barrow Arch will generally gentle dips. On the east, the Cretaceous rocks are overlain by Tertiary mixed marine and non-marine strata that have structure west of the mouth of the Canning River. East of the Canning, however, these rocks are thrown into folds with thousands of feet of structural relief and in some cases probably tens of miles of strike length. Figure 92 presents a schematic stratigraphic cross-section across the Arctic Coastal Plain-Beaufort Shelf.



Schematic cross section from Brooks Range to Beaufort Shelf

Figure 92.

Source: U.S. Geological Survey

(b) Hydrocarbon Potential

The Cretaceous rocks in the Beaufort Sea probably contain organic-rich shales at their base, as they do onshore. In addition, sands higher in the section contain both oil and gas deposits near the coast onshore. The possibility also exists that some of the pre-Cretaceous rocks which contain oil at Prudhoe Bay may locally extend across the Barrow Arch and underlie the Beaufort shelf. While the Cretaceous and Tertiary rocks are of southern provenance and thicken seaward, the pre-Cretaceous rocks are in general in shoreline facies along the Barrown Arch and thicken southward. Thus, a conservative projection of onshore data suggests that, if the prospective pre-Cretaceous rocks are present on the Beaufort shelf, they are of limited extent.

(c) Geologic Hazards

Potential geologic hazards occur primarily in the nearshore zone. Here, coastal erosion, migration of longshore bars and barrier islands, sea ice grounding and scour, and the nature of permafrost will affect the placement of pipelines and shore facilities.

b. Climate

(1) General Climatology and Seasonal Weather Patterns

Watson (1959) distinguished four climatic zones for Alaska (Figure 93) based on the absence or presence of the maritime influence. The Gulf of Alaska is in the maritime zone, characterized by small temperature variations, but high humidity, precipitation, cloud and fog frequencies. There is little or no freezing weather in this zone as the mean annual temperature is around 40°F.

Waters off the western coast of Alaska lie in the transition zone, characterized by larger daily and seasonal temperature variations and less cloudiness, precipitation, and humidity than the maritime zone. Mean annual temperature in this zone is about 25-30°F.

Waters off northern Alaska (north of the Seward Pennisula) are in the Arctic climatic zone. Temperature variations are greater than the transitional zone and strong winds are common. Precipitation is very light. Ice covers these waters in the winter, and the mean annual temperature is about 15-25°F.

(2) Sky Cover and Visibility

In the Gulf of Alaska, cloudiness is abundant, with the annual average sunrise to sunset sky cover varying from seven- to nine-tenths percent. Several locations in the Gulf exceeds 200 days a year in which the cloudiness occurs. Gulf water

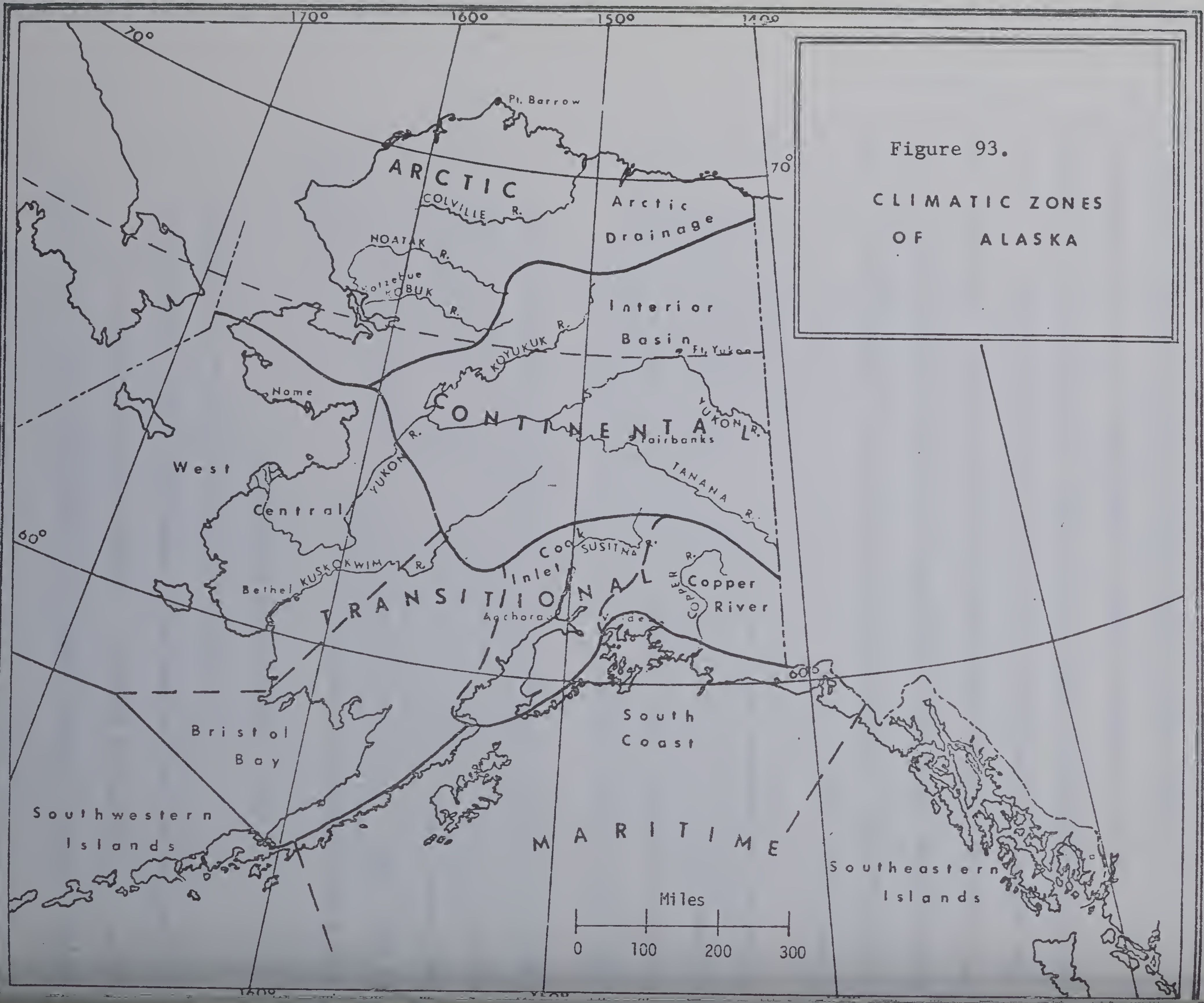


Figure 93.

CLIMATIC ZONES OF ALASKA

is warmer than the glacier-cooled air in winter and cooler than the air in summer; therefore, the occurrence of fog increases from winter to summer resulting in fog about half of the days during the summer months (Swift, et al., 1974).

In the Bristol Bay area cloud coverage is generally quite high, averaging about six- to ten-tenths during a year. Fog is most frequent during the months of July and August (Table 24).

The Bering Sea region has mean cloudiness between six- to nine-tenths. Fog occurrence is highest during the late spring and summer months.

In the Chukchi Sea area mean cloudiness varies from six- to nine-tenths and becomes a maximum during the summer months. The frequency of fog increases during the ice-free period.

Most of the Beaufort Sea is cloudy owing to the prevailing easterly wind from the Arctic Ocean. The cloud types are mainly low stratus and fog; cumuli forms are rare. The amount of solar radiation appears to have a direct relationship to the occurrence of cloudiness and heavy fog in this area. Peak cloudiness occurs during August and September when the ocean is open (Swift, et al., 1974).

(3) Surface Wind Patterns

There is wide variation in average and extreme wind speeds in different areas of Alaska. Terrain and storm tracks play an important role in determining wind flow patterns in Alaska.

TABLE 24

SKY CONDITIONS

Station	Mean Monthly Variation of Sky Cover (Tenths)	Mean Number of Days Per Year		
		Cloudy	Heavy Fog	Visibility Less Than 1/2 Mile
Anchorage	6 to 8	235	28	28
Homer	5 to 8	223	9	10
Barrow	5 to 9	188	65	
Yakutat	7 to 9	279	32	47
Cordova	7 to 9	262	12	18
Kodiak	7 to 8	185		30
King Salmon	6 to 9	244	33	35
Unalakleet	5 to 8	210	15	22
Nome	6 to 8	213	25	35
Kotzebue	6 to 8	204	20	31

SOURCE: Swift, W., et al. (1974).

Wind data for Alaska are quite limited and have been largely the by-product of aviation weather observations (Watson, et al., 1971).

During the winter months it is not out of the ordinary to have storm-caused winds in excess of 50 mph along the Arctic Coast. Wind speeds greater than 70 mph have been experienced in winter months along the Arctic Coast (Searby, 1968). These strong and rather persistent Arctic winds tend to parallel the coastline from Barrow to Barter Island, resulting in prevailing winds holding to easterly or westerly directions. Although wind speeds at Barrow average slightly less than speeds at Barter Island, Barrow has recorded a maximum speed greater than 100 mph which occurred in the month of January (Watson, 1959).

Searby (1969) reports that two types of strong surface winds occur in the Gulf of Alaska. One type is a very narrow band, produced by a strong pressure gradient, and reinforced by the venturi effect of deep narrow valleys. These winds are usually perpendicular to the coast and extend outward over water up to 30 miles from the coast. For example, with this type of wind, ships crossing the Copper River outlet will experience abrupt changes of speed upon entering and leaving the narrow band of wind. To our knowledge speed measurements for this type of wind have not been made. Estimates indicate that gusts of 100 to 120 mph are quite possible under extreme conditions.

The other type of wind occurs with storms that frequent the Gulf of Alaska. These much broader bands of wind may persist for periods of one to three days with little change. Speeds over water will occasionally reach 75 to 100 mph.

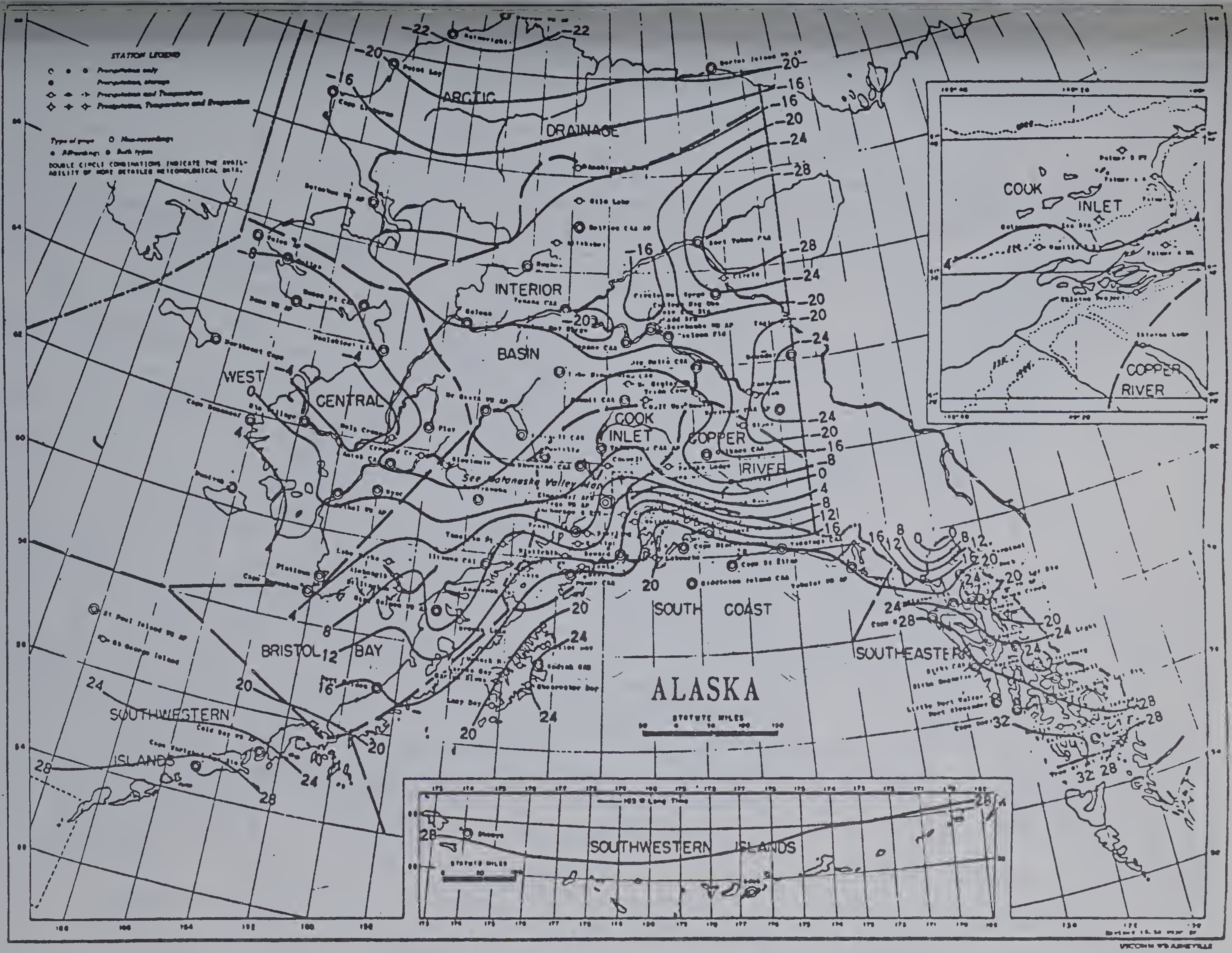
(4) Air Temperatures

In the maritime zone the summer to winter range of average temperatures is from near 60 to the 20's. In the transition zone, temperatures range from the low 60's to near zero, except for the cooler northern coastal region of the western-central division areas where the range is from the mid-50's to near 10 below zero. The Arctic Slope has a range extending from the upper 40's to 20 below zero (Searby, 1969).

Figures 94 through 97 illustrate in greater detail the mean maximum and minimum temperatures for the months of January and July. Although the temperatures on these figures apply mainly to terrestrial areas, relative temperatures experienced over adjacent waters can be estimated by extrapolation.

(5) Precipitation

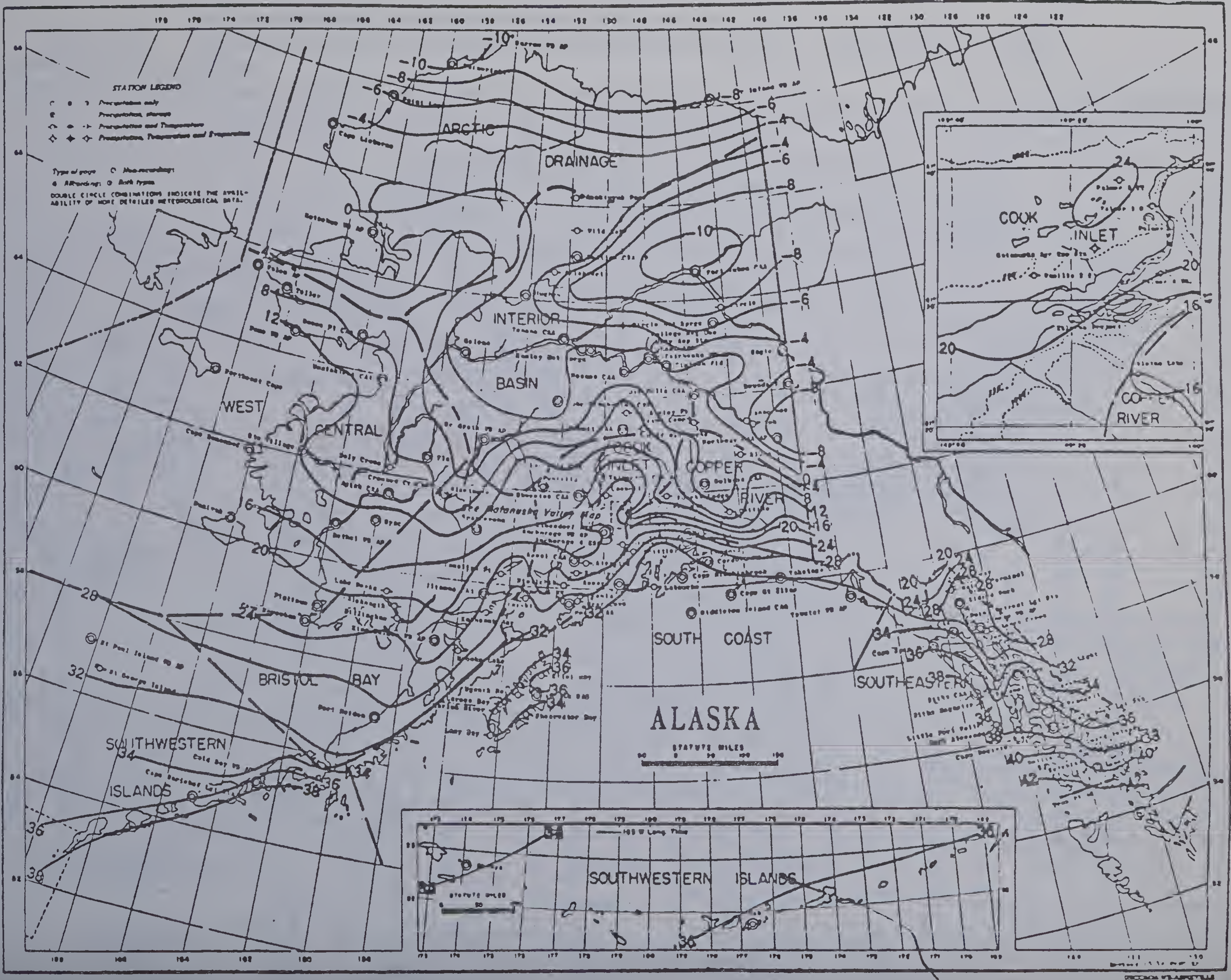
Offshore precipitation in Alaska appears to be inversely related to the latitude, although local variations such as coastal topography and water masses are important. Figure 18 indicates the mean annual precipitation of continental Alaska. Over



Based on period 1931-52

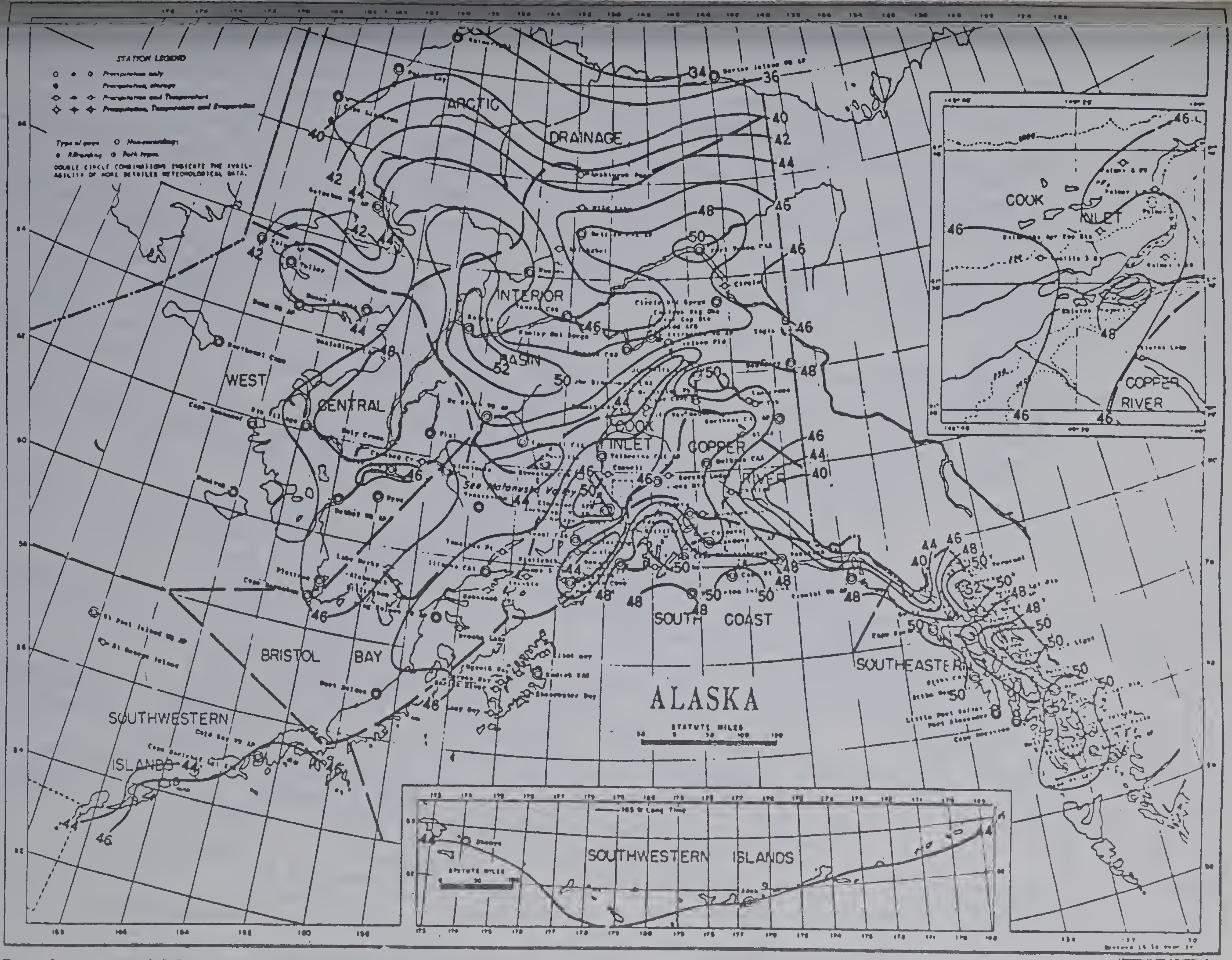
Figure 94. Isolines are drawn through points of approximately equal value. Caution should be used in interpolating on these maps, particularly in mountainous areas. From Searby, 1968.

Mean Maximum Temperature (°F.), January



Based on period 1931-52

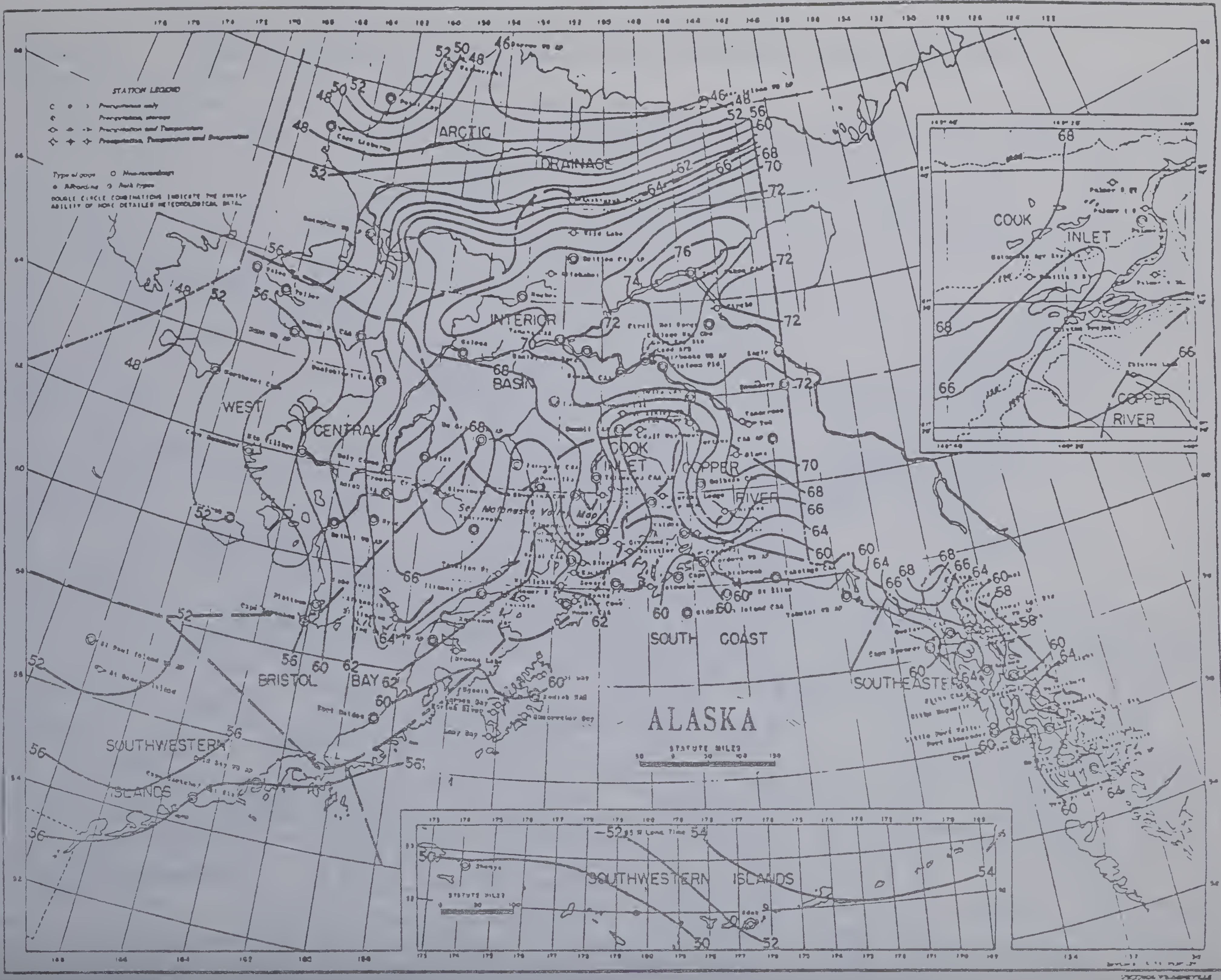
Figure 95. Isolines are drawn through points of approximately equal value. Caution should be used in interpolating on these maps, particularly in mountainous areas. From Searby, 1968.



Based on period 1931-52

Figure 96. Isolines are drawn through points of approximately equal value. Caution should be used in interpolating on these maps, particularly in mountainous areas. From Searby, 1968.

Mean Maximum Temperature (°F.), July



Based on period 1931-52

Figure 97. — Isolines are drawn through points of approximately equal value. Caution should be used in interpolating on these maps, particularly in mountainous areas. From Searby, 1968.

Mean Annual Precipitation, Inches

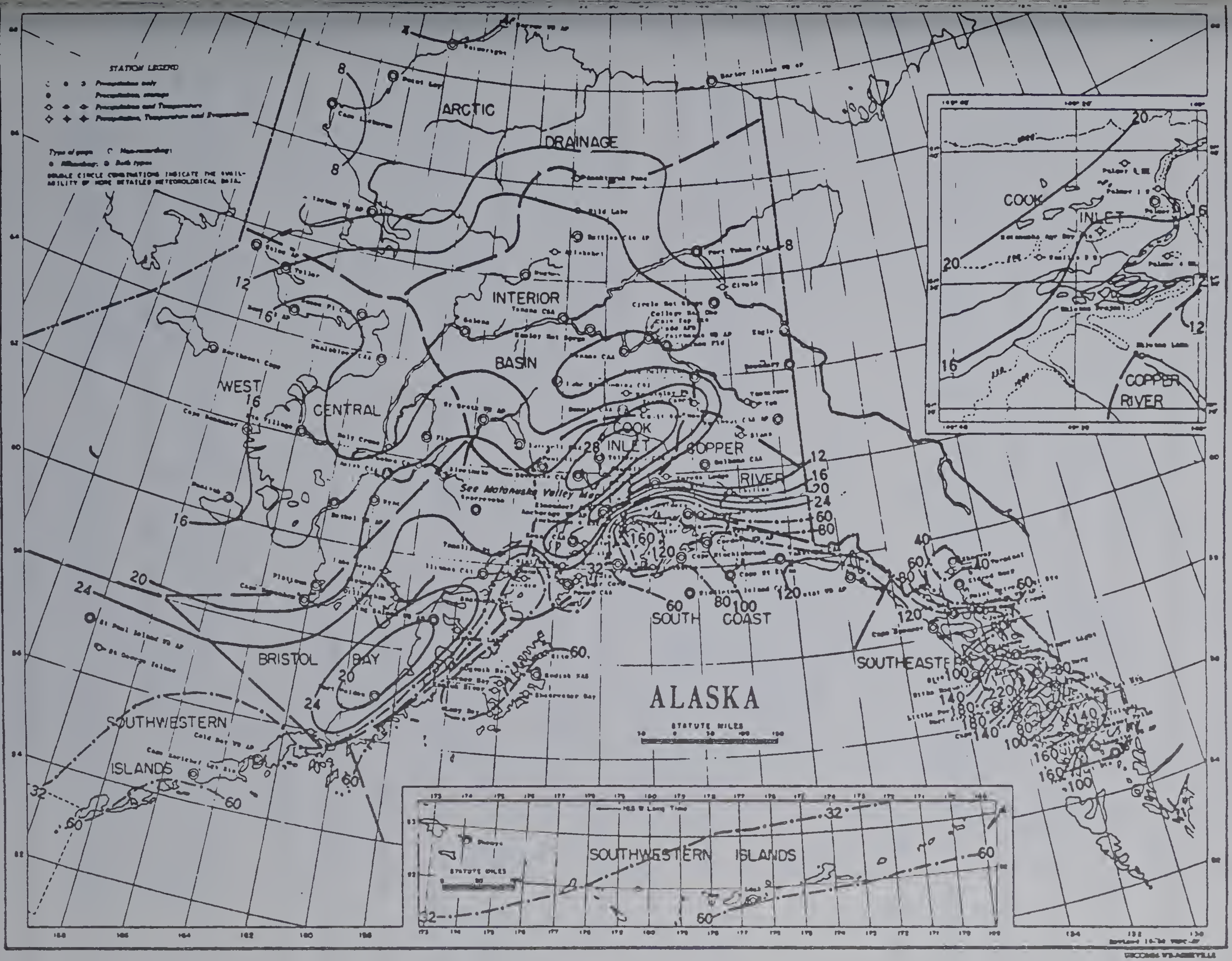


Figure 98. Isolines are drawn through points of approximately equal value. Caution should be used in interpolating on these maps, particularly in mountainous areas. From Searby, 1968.

200 inches of moisture fall in parts of the southwestern panhandle which is in the maritime climatic zone. Farther north and west, precipitation amounts decrease rapidly, being very slight in the transitional and arctic climatic zones. Figure 98 clearly shows the influence of coastal topography on precipitation in Bristol Bay. The Aluetian Range acts as a moisture barrier to the moisture-laden air masses in the Gulf of Alaska, resulting in a zone of low rainfall in Bristol Bay.

(6) Storms

The Gulf of Alaska and the area south of the Aluetian chain are well-known as areas of cyclogenesis (storm origin). Storms are frequent and of high intensity, producing large quantities of precipitation and strong winds. Figures 99 and 100 show average sea level pressure patterns and major storm tracks for winter and summer months, respectively. The intense gradients between the Aleutian low pressure cell and the Arctic high pressure cell during winter generates the strong surface winds. During the summer, pressure gradients decrease markedly as the Aleutian low pressure area nearly dissipates.

The Bering Sea area is often influenced either by storms originating in the Bering Sea or those which move northeasterly from storm centers in the Aleutian Islands. Farther north, in the Chukchi Sea, high-velocity winds accompany passing storms.

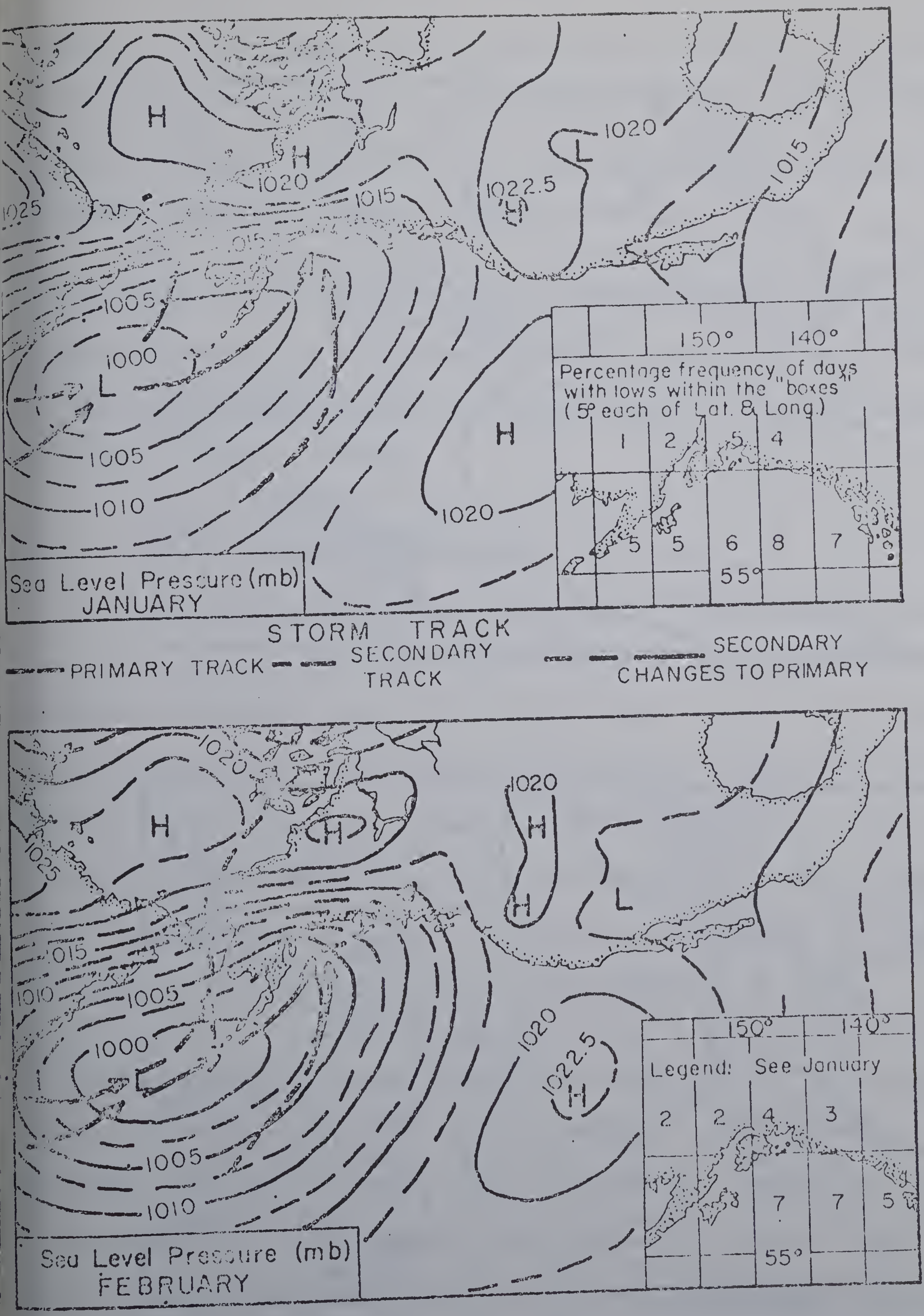


Figure 99. Average sea level pressure pattern and major storm tracts, January and February. (Reprinted from Searby, 1969.)

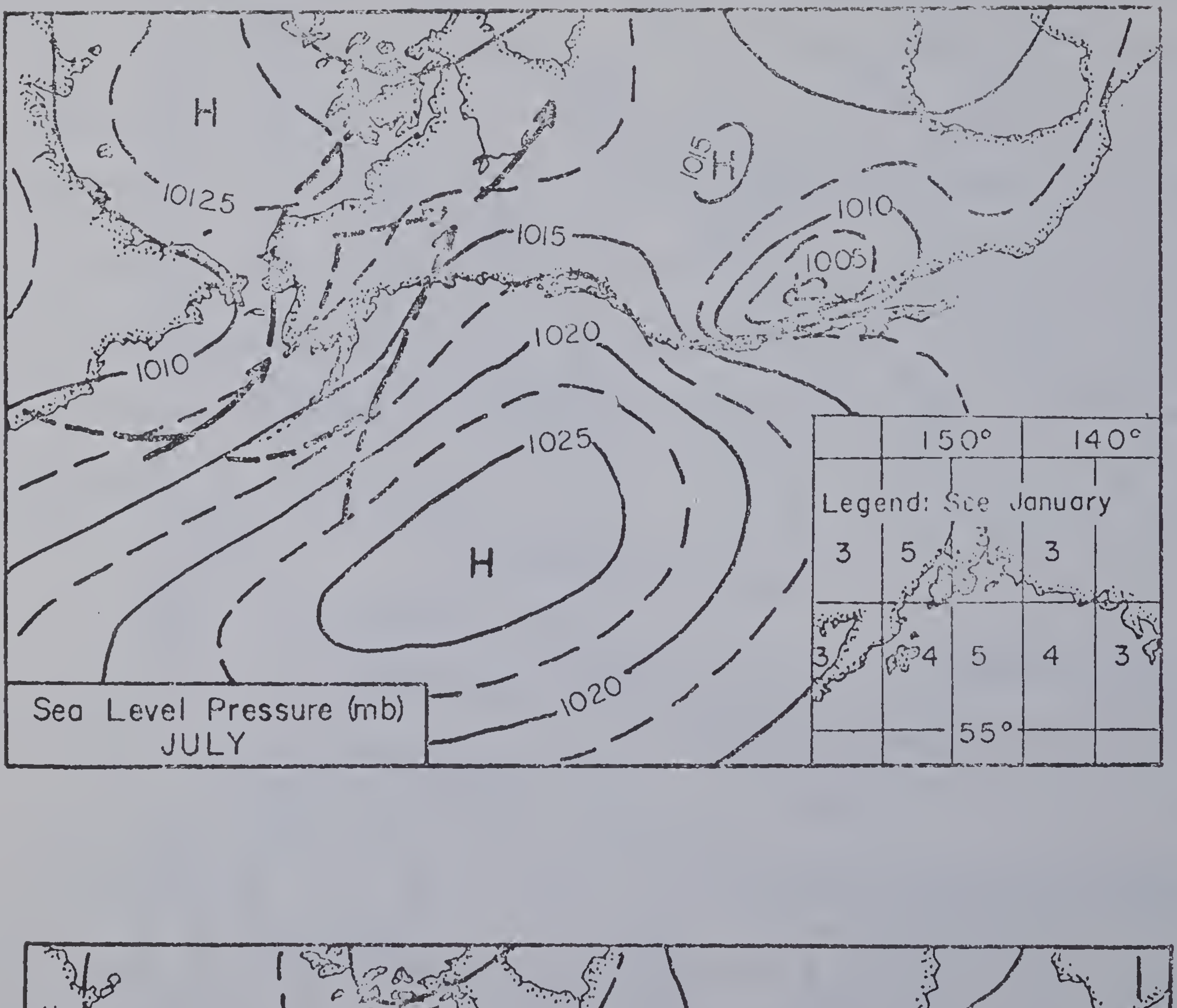


Figure 100. Average sea level pressure pattern and major storm tracts, July and August. (Reprinted from Searby, 1969.)

Waters off the northern coast of Alaska are not generally areas of storm generation, although storms generated elsewhere may pass through this area. As indicated by Searby (1971) surface winds are extremely persistent, flowing predominantly to the east.

Figure 101 illustrates the percentage of storms occurring within five degree squares in the Alaska region. Storm centers are most common in the Gulf of Alaska during the months of October, November, and December.

c. Physical Oceanography

(1) Surface Sea Temperatures

Sea surface temperatures in Alaska waters reflect surface circulation patterns to a large extent. In general, offshore surface temperatures decrease as the water flows northward and westward in the Gulf of Alaska. Temperatures range from about 45°F. (winter) to 55°F. (summer) in the western Gulf (U.S. Dept. of Commerce, 1961). Temperatures decrease by 5 to 8°F. as the water flows past the Aleutian Islands into the Bering Sea.

Within the Bering Sea, water temperatures range from 30°F. (near the winter ice cover), about 50°F. near Bristol Bay in the summer, to less than 40°F. north of Point Hope in the summer. Figures 102 and 103 illustrate Alaska water temperatures in summer and winter, respectively. Local variations are common due to river runoff, topography and other factors.

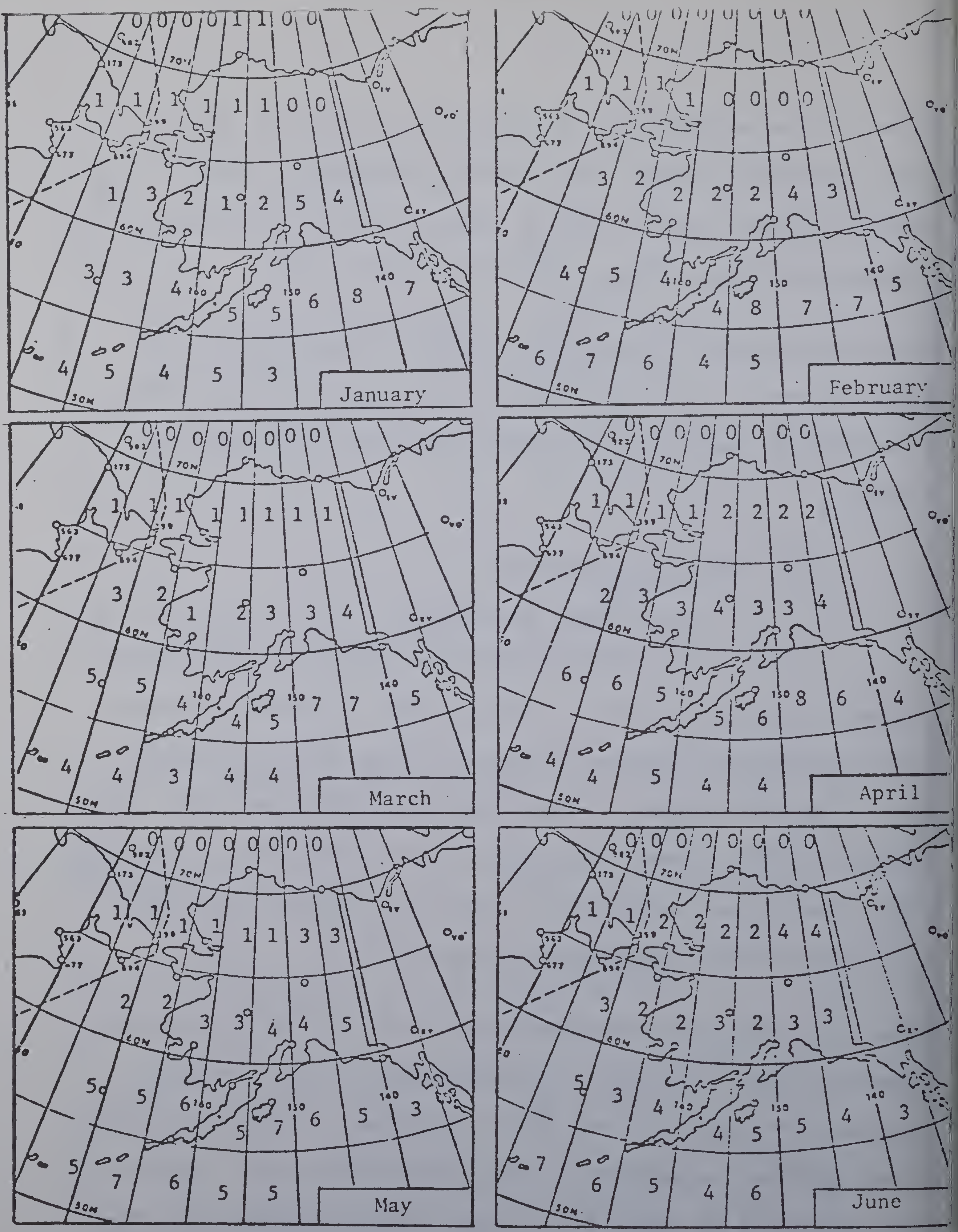
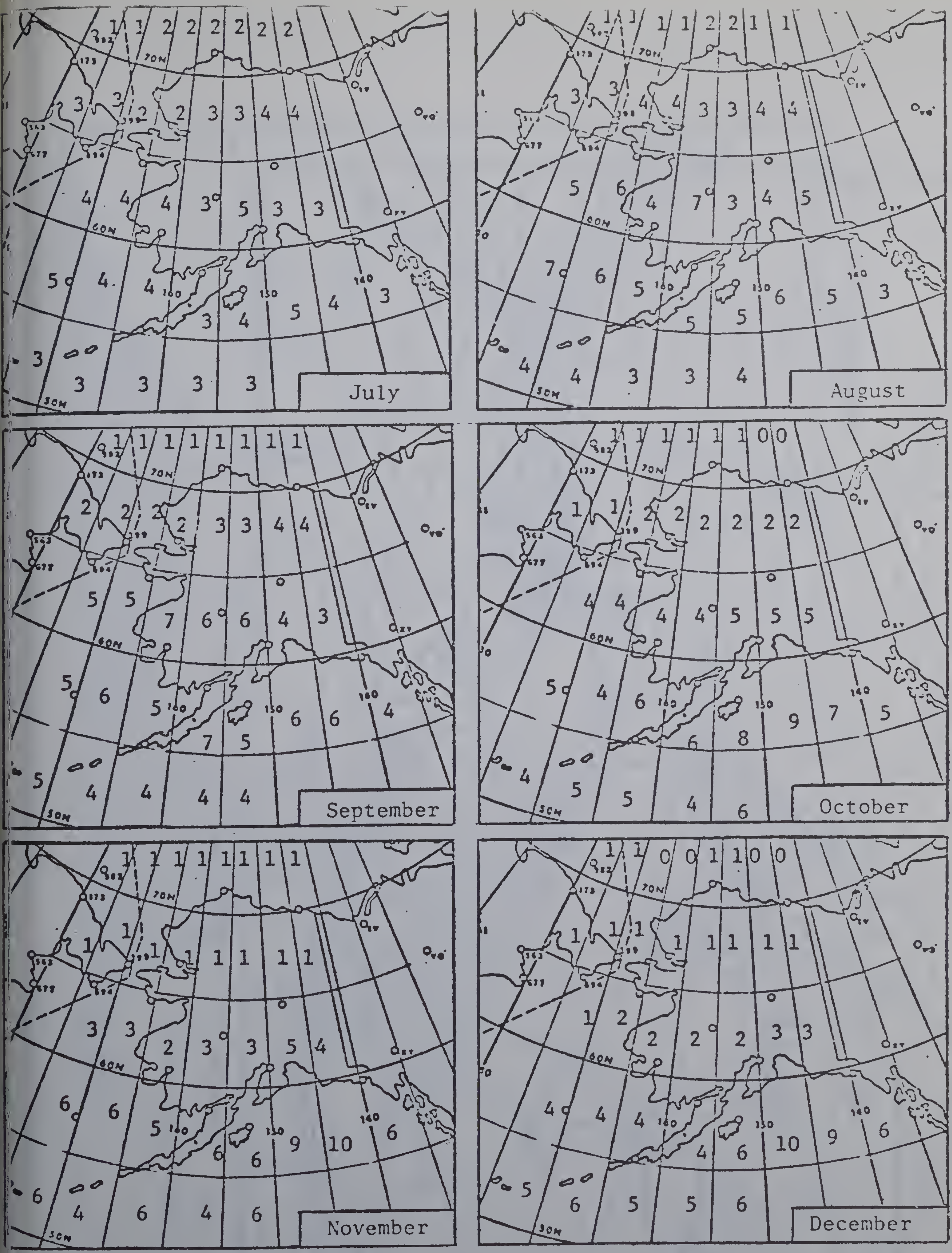


Figure 101. Storm Frequency, North Pacific. Percentage frequency of the number of days with lows or storm centers in five degree square. Forty years of record (Navy Hydrographic Office 1961).



gure 101, Continued.

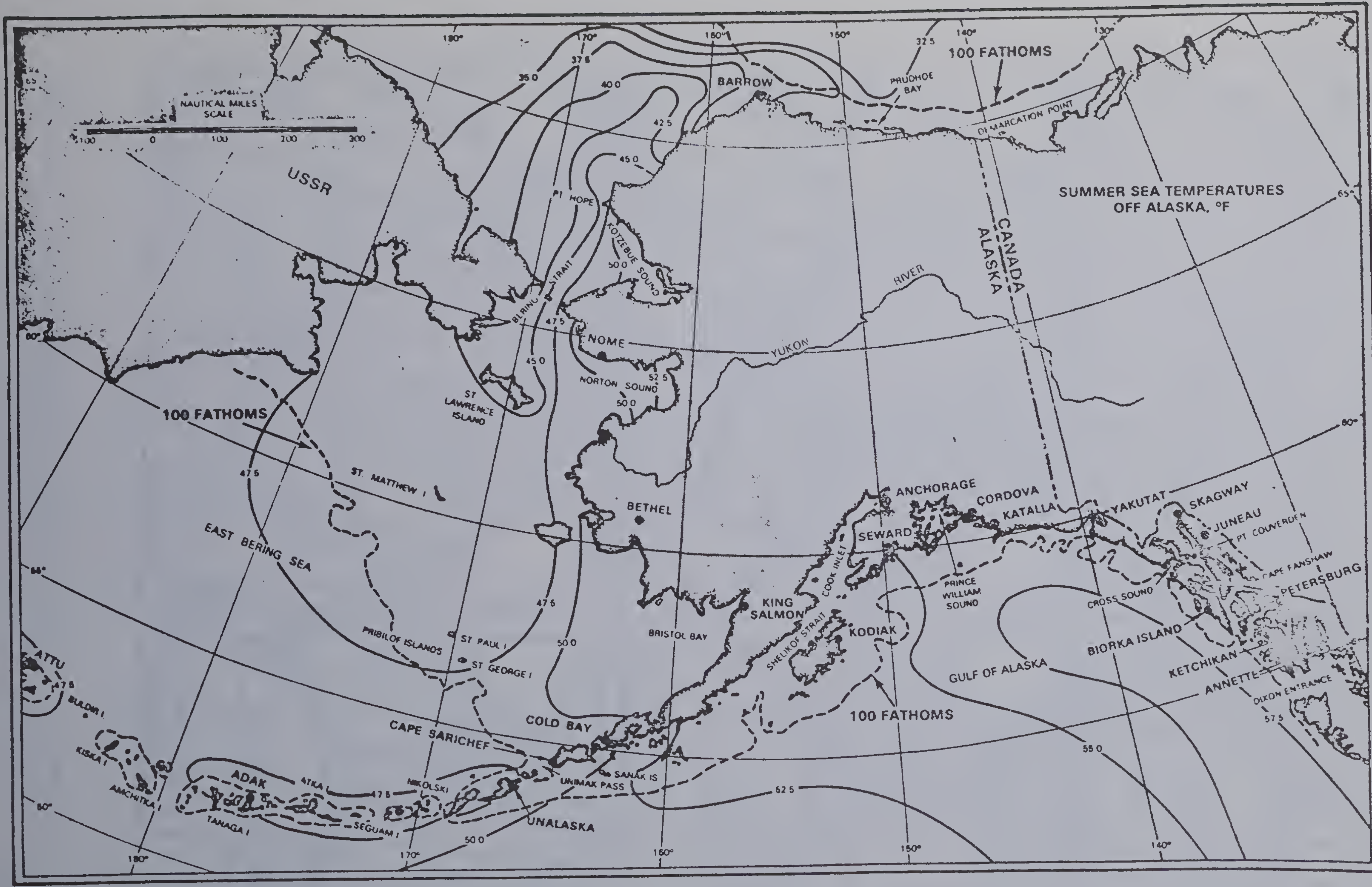


FIGURE 102. SUMMER SEA TEMPERATURES OFF ALASKA (°F)

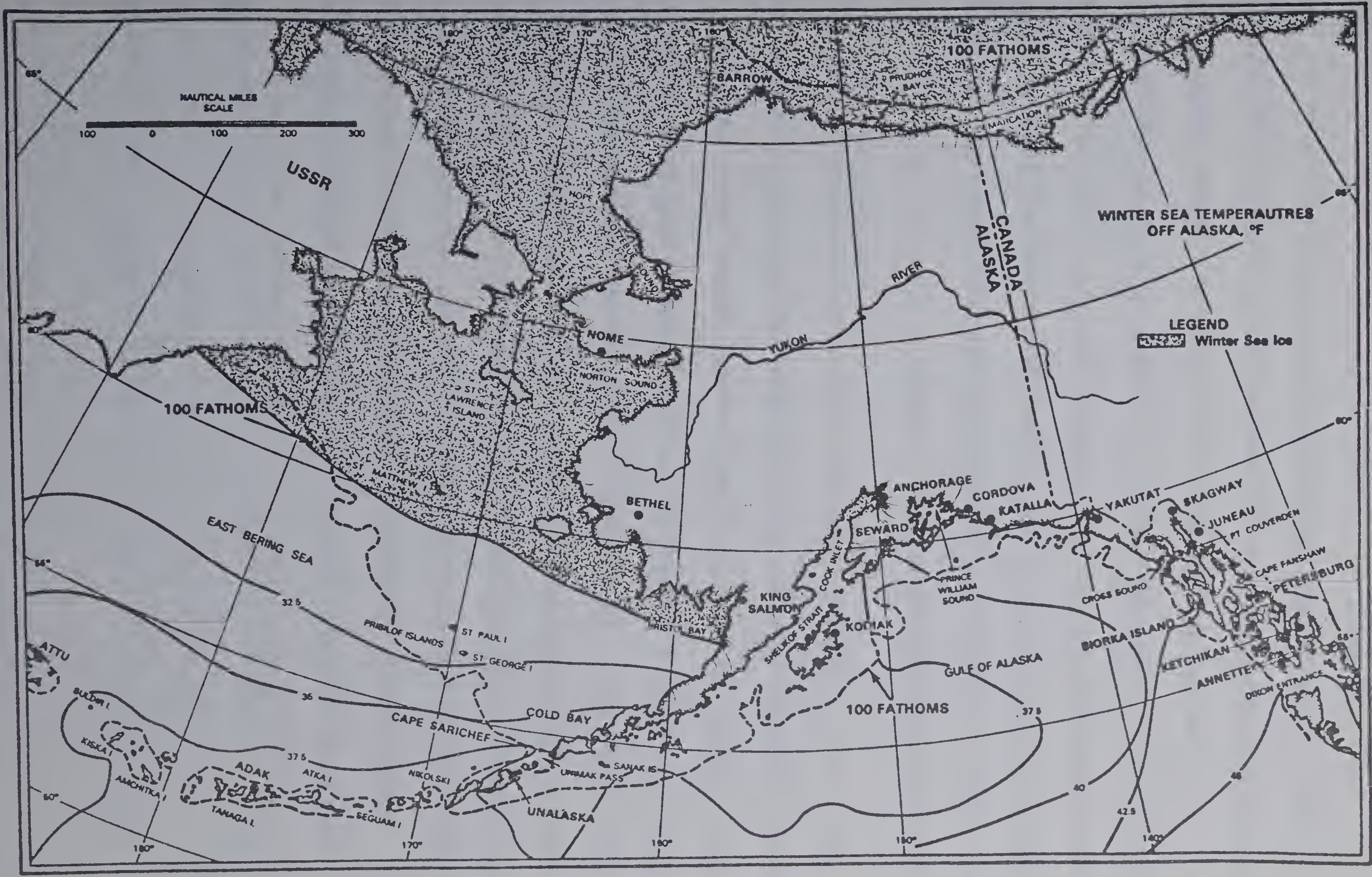


FIGURE 103. WINTER SEA TEMPERATURES OFF ALASKA (°F)

(2) Salinity

Salinity, like temperature, is associated with the ocean circulation patterns. Highest surface salinities (32.7^{o}/oo) are found in the central Alaska gyre (the major circulatory current system in the Gulf of Alaska). Closer to shore, salinities decrease considerably, particularly along the western shore of the Gulf of Alaska where salinities as low as 21.7^{o}/oo have been reported (Robinson, 1957). These minimum salinities are attributed to abundant precipitation and continental runoff.

In the Bering Sea salinities decrease progressively northward from the Aleutian Islands. Much of this decrease results from Bristol Bay runoff into coastal Gulf of Alaska waters. To a lesser extent, ice melt in the spring and a greater rate of precipitation contribute fresh water to the Bay. As the water flows northward towards the Chukchi Sea, surface salinity continues to decrease. Bialek (1966) indicates maximum salinities of 31.0^{o}/oo in the Chukchi Sea and less than 27.0^{o}/oo in the Beaufort Sea off Point Barrow. These conditions produce a distinct separation between the less-saline, less dense surface waters and the much more saline sub-surface waters. Vertical mixing is therefore greatly reduced except for periods of high turbulence.

(3) Surface Circulation

Offshore circulation in Alaska waters begins with the "West Wind Drift", a slow eastward-flowing current between 40° and 50° north latitude (Fig. 104). As this current encounters the North American coast it branches to the north and south. The northern branch becomes the warm Alaska Current, flowing counterclockwise and roughly parallel to the arcing coastline. Part of this current enters the Bering Sea through the Aleutian Islands, although the major portion of flow continues on and rejoins the West Wind Drift at the tip of the Aleutian Islands.

This description is rather simplistic; the actual circulation patterns are quite complex. Meanders and reversals often occur due to weather conditions, bathymetry, and nearshore topography. Plakhotnik (1964) estimated average current speeds as follows: 0.1 to 0.2 knots in the West Wind Drift; 0.3 to 0.4 knots in the western Gulf of Alaska; increasing to 1.0 to 1.5 knots along the northern Gulf coast and the Aleutian Islands. The swiftness of the current in the latter region is related to the decrease in depth as the water encounters the continental slope and the shallow continental shelf.

Offshore Alaskan currents have been measured only sparsely. Logs of ships' drift, geostrophic calculations (based on density inbalances), and theoretical wind-stress calculations have been

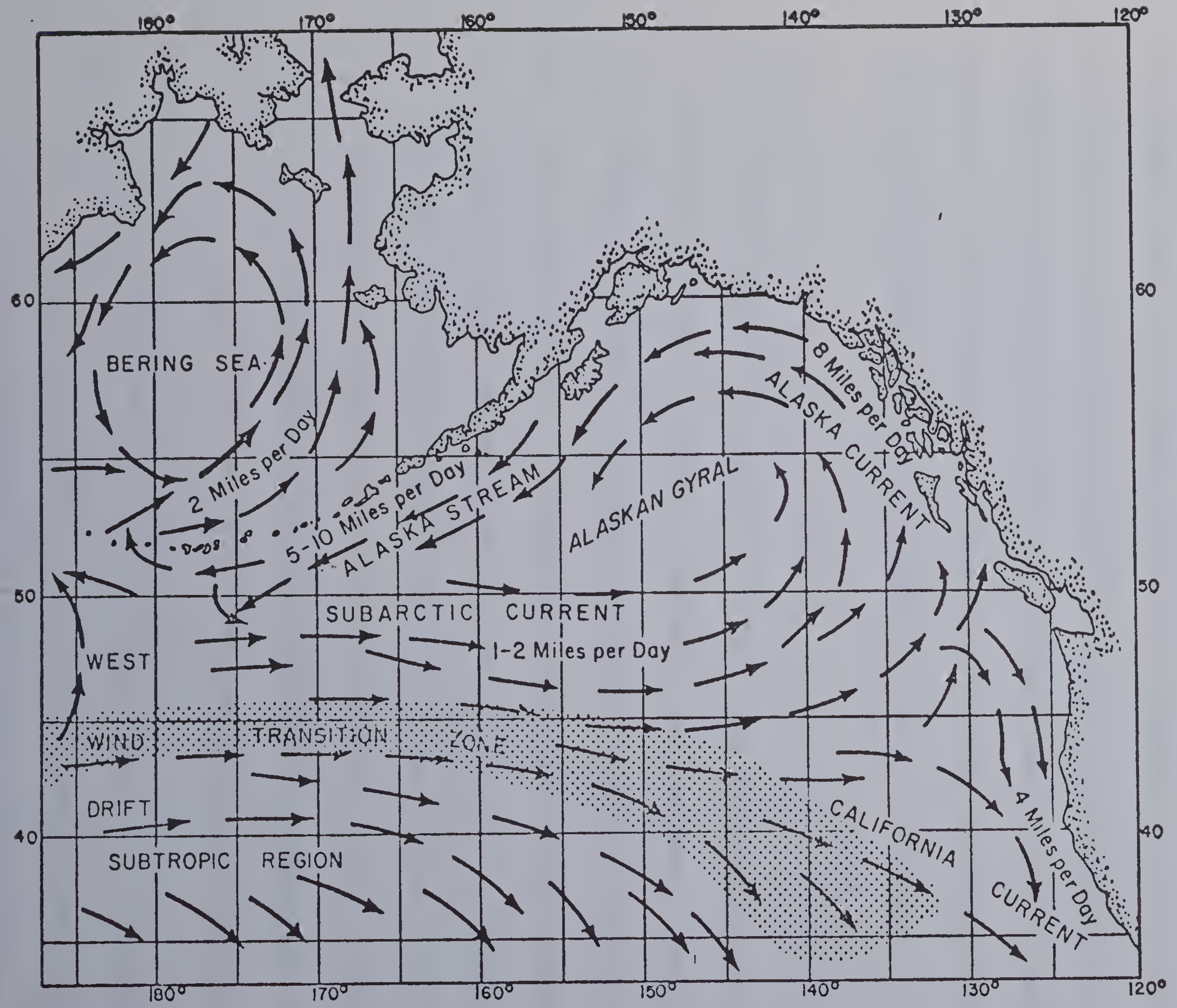


Figure 104. General circulation, North Pacific Ocean--1 mi./day ≅ 2 cm./sec; 50 cm./sec. ≅ 1 knot (adapted from Dodimead, Favorite, Hirano 1962).

used to infer general circulation patterns. Additional information has been derived from drift bottle experiments which have been performed sporadically for many years.

The primary driving forces behind the offshore circulation in the Gulf of Alaska are the geostrophic (due to ocean pressure gradients and the earth's rotation), and wind-stress components. Geostrophic calculations based on numerous hydrographic cruises have presented fairly consistent estimates of current speed and direction. Current speeds in the main Alaskan gyre are rather slow as estimated by this method, but increase in the northern and western areas of the Gulf.

The stress of the wind blowing over the water can reinforce the geostrophic flow, particularly during the winter months when strong winds are associated with the Aleutian low pressure system. Roden (1969) determined that the winter intensification of current flow is very closely associated with the low pressure field. This added wind stress alone may produce current velocities in excess of 20 cm/sec. near the continental slope.

Of the water which flows into the Bering Sea from the Gulf of Alaska, a major portion flows through Unimak, Amukia and Amchitka Passes. This water mixes with eastward flowing waters along the northern shores of the Aleutians. The resulting mixture, augmented by Bristol Bay outflow and the Kuskokwim and Yukon Rivers, moves north until it branches nears St. Lawrence Island. One branch moves to the west along the shores of Kamchatcha while the other branch flows through the Bering Strait into the Chukchi Sea. According to N.A.S. (1970), about 20% of the Bering Sea inflow into the Chukchi Sea is a mixture of sea water and terrestrial runoff. (The remainder is Bering Sea water, ice melt water, and residual water of the Chukchi Sea.)

The counterclockwise circulation in the Bering Sea is thought to be largely wind-driven (Gurikova, et al., 1964). These currents, generated by a non-uniform wind field over the Bering Sea, tend to "draw" Gulf of Alaska water through the Aleutian Island passes. Currents over the continental shelf are chiefly tidal and can be locally significant. For example, tidal currents through Unimak Pass exceed 3.5 knots.

Little information is available for currents in the Chukchi and Beaufort Seas, probably because ice covers the area for a majority of the year. From records of vessel and ice island drifts, descriptions are available for the Arctic Ocean (Beaufort Sea) and the Chukchi Sea (U.S. Naval Oceanog. Off., 1958).

Circulation in the Chukchi Sea appears to be sluggish, moving generally counterclockwise. Current speeds vary considerably, depending on river runoff, ice melt and winds. Water flows northeastward until it reaches Point Barrow. Here it encounters the westerly flowing

Beaufort Sea currents, and the resultant flow is offshore. For the most part, currents in the Arctic region are extremely variable, in both speed and direction, depending on the local winds.

(4) Tides

The tide may be considered as a shallow water wave which travels around the earth, largely under the influence of the moon's gravitational attraction, and to a lesser extent, the attraction of the sun.

The tide wave moves in a northwesterly direction in Alaska waters. This tends to accentuate the height of the tide since the wave shoals or impinges on the continental shelf. Furthermore, the physiography of Alaska tends to magnify the effect even more (Fig.105). Triangular bays (such as Bristol Bay and Cook Inlet) "funnel" the tide towards the apex, creating very large tidal heights. Ranges greater than 20 and 30 feet have been reported at Bristol Bay and Cook Inlet, respectively. The large tidal ranges play an important and conspicuous part in the circulation and mixing processes, especially along the Gulf of Alaska and Bristol Bay shores.

Tide ranges decrease rapidly north of Bristol Bay. Beyond the Bering Strait tide ranges are generally less than one foot during ice-free periods. Very small ranges occur during the winter months when ice covers the ocean surface. Of greater consequence is the set-up

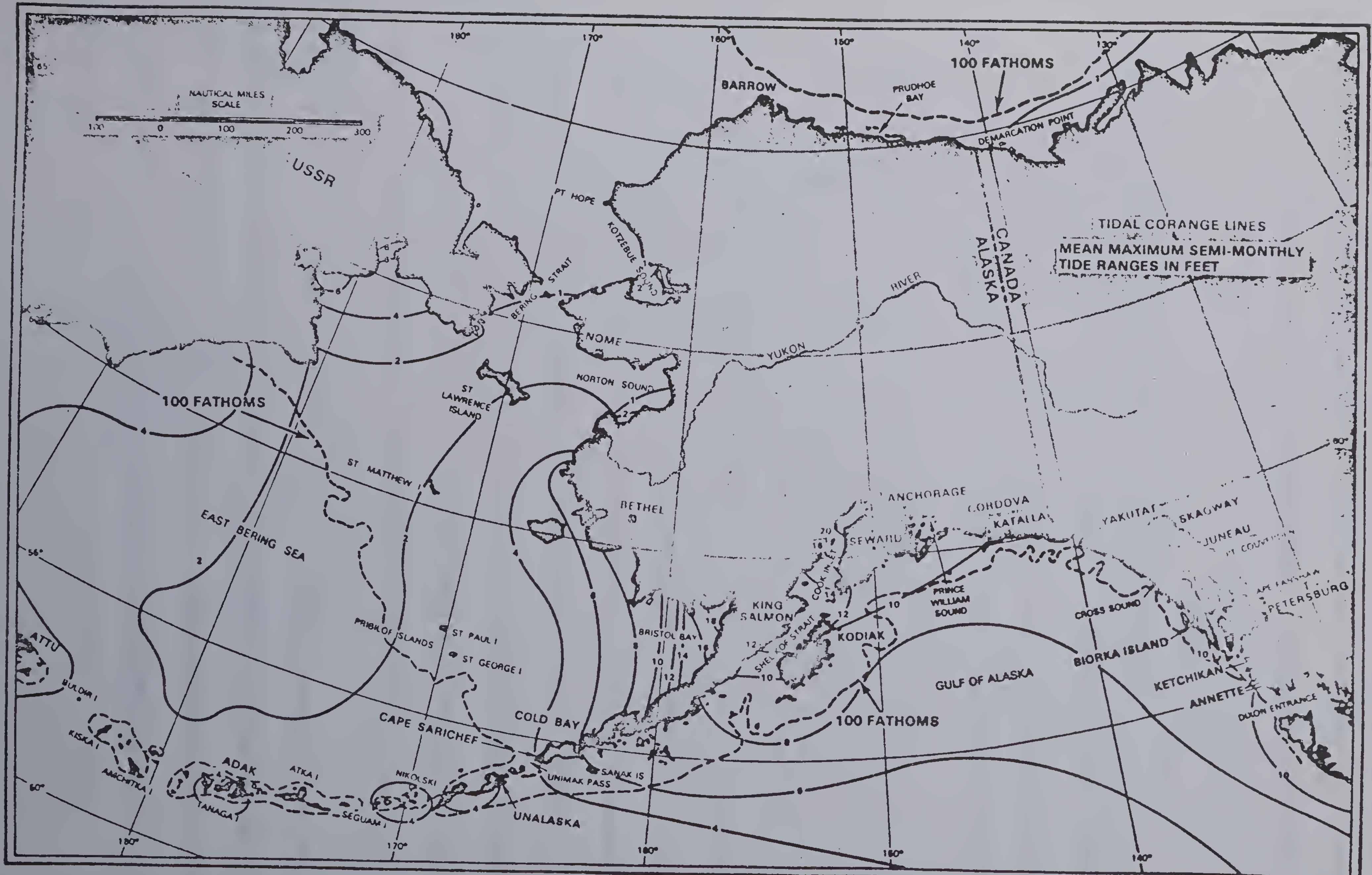


Figure 105. TIDAL CORANGE LINES

(rise in water level) caused by rapid decreases of barometric pressure or onshore winds. The changes in sea level due to these latter forces can be as much as five feet (Swift, et al., 1974).

(5) Sea and Swell

Sea, the waves produced locally by wind, is distinguished from swell in that the latter is the series of waves which are generated outside an area and are moving through that area. Locally generated sea tends to be the dominant form of wave motion in Alaskan waters. Even swell, generated outside Alaskan waters, undergoes modification by large storms in the Alaskan area. Sea, as opposed to swell, is irregular in height and period. Wave crests tend to be peaked and induce considerable motion to ships and other floating objects.

Autumn appears to be the stormiest season in the Gulf of Alaska and therefore produces the roughest seas. In spite of the severity of the storms and the intensity of the winds, no waves greater than 30 feet have been observed (Searby, 1969). A recent study (G.A.O.C., 1973) suggests there is less than 25% probability of offshore waves exceeding 14 feet in the Gulf of Alaska.

From Figure 106 it can be seen that rough sea conditions occur much less frequently in the Bering Sea than in the Gulf of Alaska. The eastern Aleutian Islands experience considerably less severe wave conditions

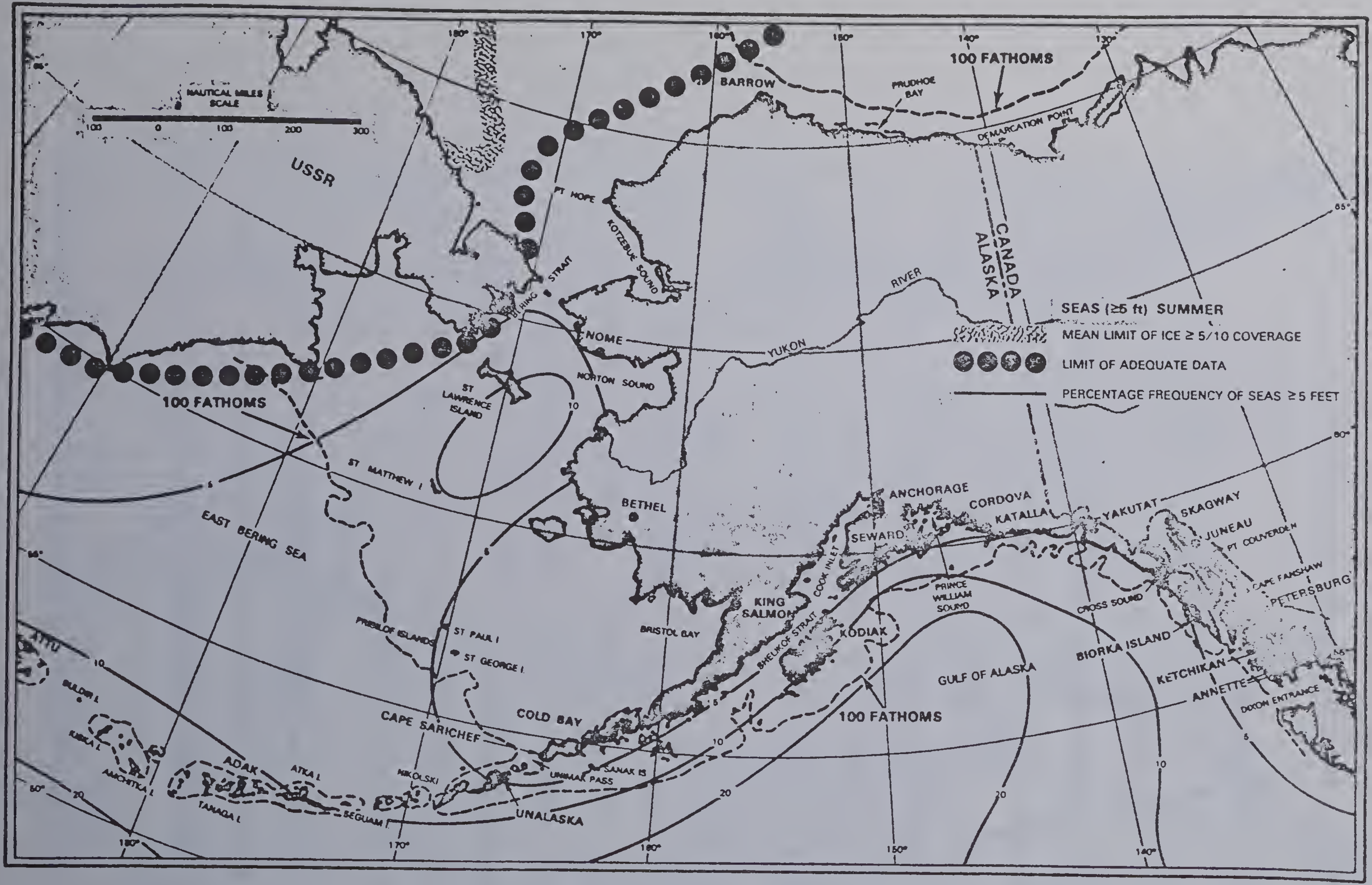


Figure 106. SEAS (≥ 5 FEET) SUMMER

than the islands farther offshore. Seas in the Chukchi and Beaufort Seas are relatively calm as wind influence over the water surface is limited by distance (fetch).

In winter months, the frequencies of wave heights greater than 5 feet are about twice those given in Figure 106 (U.S. Dept. of Commerce, 1961). Ice coverage extends just south of 60° north latitude, so that no waves occur in the northern Bering Sea and the Chukchi and Beaufort Seas during this season.

d. The Biological Environment

Marine biological environments of Alaska are grouped by their ocean or sea of origin because of the large size of the area. The groupings, based on natural separations, are the Gulf of Alaska, the Bering Sea, and the Artic Ocean. Where information is available, each area will be discussed individually.

(1) Phytoplankton

Marine phytoplankton production in all areas of Alaska is markedly seasonal. In these high latitudes, primary productivity (phytoplankton growth) is directly related to available light. Maximum production occurs during the artic summers when daylight is nearly continuous.

In addition to sunlight, several other physical parameters are important to primary production. If the depth of surface layer mixing is so great that the phytoplankters are below a specific level of light, their respiration requirements may exceed the organic matter they produce. This results in a net energy loss and the population decreases. However, if the wind-mixed layer (or ocean bottom) is less deep than the "critical depth" (Sverdrup, 1953) mentioned above, photosynthesis provides a net gain and the phytoplankton population increases, providing nutrients are not limiting.

The few studies completed within the Gulf of Alaska indicate several general conclusions. Total annual primary production may be two to four times greater on the continental shelf than in the open ocean (Cooney, 1972), although Larrance (1971) indicated the difference between coastal and open ocean values may not be so large. Gulland (1972) pointed out that productivity estimates in the open ocean (Ocean Station P) in 1969 are only one-half the 1960-1965 values. Therefore, comparisons from different years are of little value.

Figure 107 indicates estimates of daily primary productivity for the Gulf of Alaska during the summer. The Aleutian Islands and the Bering Sea are shown to be regions of high productivity during the summer. Annually, production estimates generally decrease to the north. Larrance (1971) found annual production in the Gulf of Alaska to be about 80 to 100 g C/m^2. Gulland (1972) estimated annual production to be about 150 g C/m^2 along the coastal strip. These values compare with extremely high production (over 600 g C/m^2 in the southeastern part of the Bering Sea (Azova, 1964). Production decreases significantly farther offshore in the Bering Sea and Chukchi Sea. Primary production is very low in the Arctic Ocean as estimates of less than 1 g C/m^2/yr have been reported.

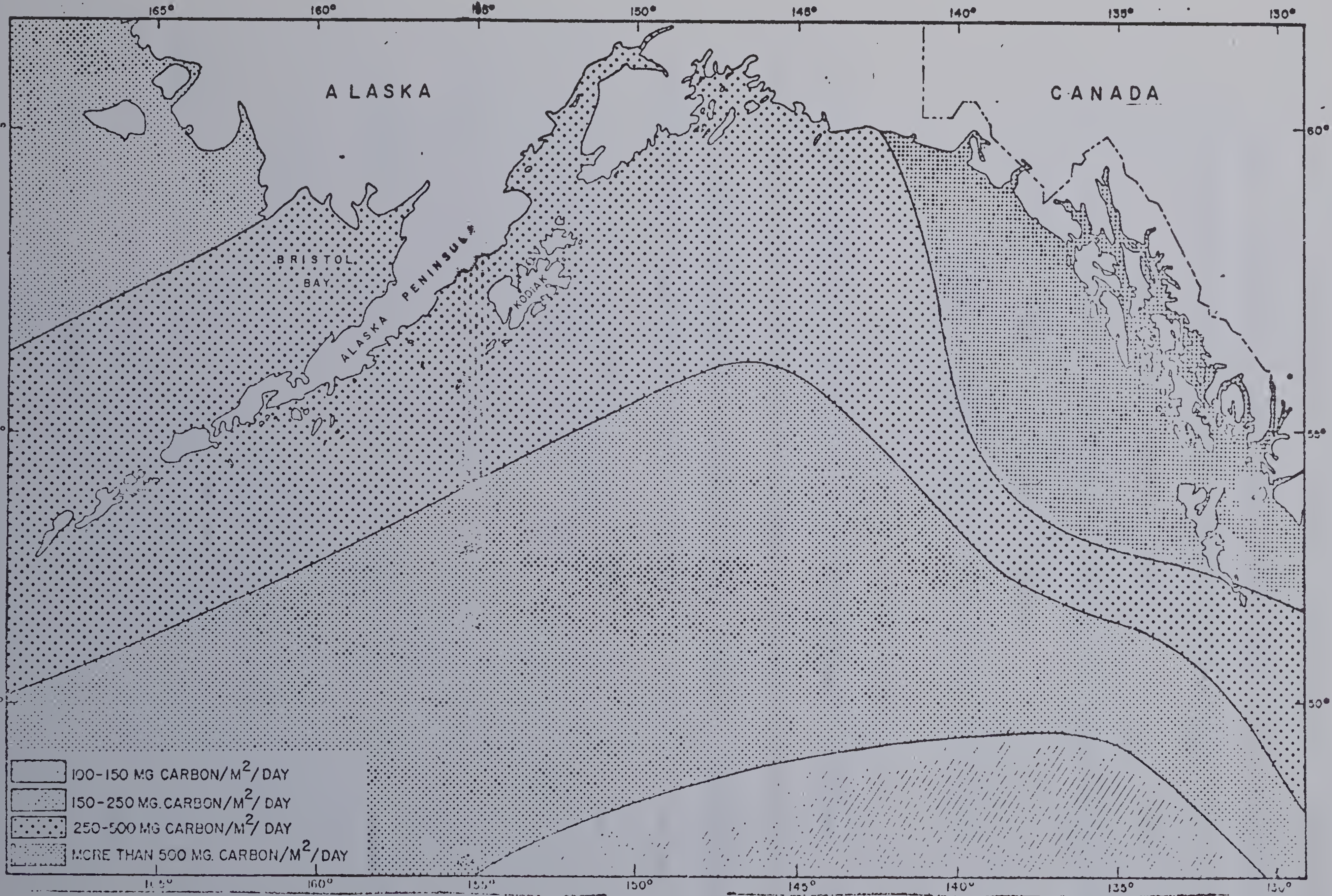

165°
160°
155°
150°
145°
140°
135°
130°
60°
55°
50°
ALASKA
CANADA
BRISTOL BAY
ALASKA PENINSULA
KODIAK
100-150 MG CARBON/M²/ DAY
150-250 MG. CARBON/M²/ DAY
250-500 MG CARBON/M²/ DAY
MORE THAN 500 MG. CARBON/M²/DAY

Figure 107. Phytoplankton productivity in the North Pacific Ocean (from Food and Agriculture Organization of the United Nations 1972).

These very general estimates may be characteristic of a large scale production pattern, but much higher or lower values may occur in specific areas.

The dominant type of phytoplankton in the Gulf of Alaska are the diatoms, in both absolute numbers and number of species. Cupp (1937) reported 87 species of diatoms, and 21 species of dinoflagellates occurring at Unimak Island. Temperate species were most numerous, with the diatom genera *Asterionella*, *Thalassiosira*, and *Chaetoceros* being of major importance. There were no large populations of dinoflagellates in comparison to diatoms. *Ceratium*, *Dinophysis*, *Peridinium*, and *Gonyaulax* were the most common dinoflagellate genera.

A unique community of phytoplankton occurs within the diffuse lower layers of first-year sea ice. These plants live in or on the ice, actively growing when solar radiation is present. This ice algae reaches a growth peak near the end of May in the artic, then declines abruptly as the ice breakes up in summer.

(2) Zooplankton

Zooplankton populations of the North Pacific have enjoyed more extensive investigations than the phytoplankton. However, there is a direct relationship between the "grazers" (herbivorous zooplankton) and the marine "grass" (phytoplankton). In general, peaks of zooplankton abundance closely follow peaks of phytoplankton abundance.

Zooplankton, as the name imples, are carried by the currents, but they can undergo significant daily vertical migrations (to 800 meters). These migrations have some ecological significance. Possibilities include maximizing forage, minimizing predation, increasing reproductive potential, and others.

One consequence of zooplankton migration appears to be the "hibernation" of zooplankton in the deep oceanic waters during winter when there is essentially no phytoplankton on which to graze. When the spring phytoplankton "bloom" occurs, oceanic zooplankton migrate upward to forage. However, in the shallow coastal waters of the Gulf of Alaska and the Bering Sea, there is no deep water to harbor the zooplankton, and as a result, there is a considerable lag between phytoplankton - zooplankton abundance peaks.

The seasonal abundance of zooplankton in the Gulf of Alaska follows the pattern of phytoplankton. During the winter, zooplankton biomass is at its lowest. In March, grazers appear in the surface waters, increasing in number until reaching a peak in late May. From data collected at Ocean Station P, the peak standing stock of zooplankton was about 175g per 100m^3 of water (Le Brasseur, 1965).

Copepods are the dominant form of zooplankton in the Gulf of Alaska, especially *Calanus plumchrus*. Several other copepods, *C. pacificus*, *C. Cristatus*, and *Eucalunus* sp. were also present at Ocean Station P (McAllister, 1961). Chaeotognaths were the second most abundant group, while the dominant amphipod was the euphausiid *Prathemisto pacifica*. Euphausiids represent a major food source for many major groups of commercial fishes, such as salmon, cod, herring and pollock.

Although less well known and considerably less common, the zooplankton biomass also consists of mysids, pelagic shrimp, fish larvae and small fish. Most of these forms also under daily vertical migrations.

Zooplankton studies in the Bering Sea have indicated that large variations in abundance occur. Meshcheryzkova (1970) suggested the degree of penetration of North Pacific water into the Bering Sea was responsible for this variability. Zooplankton were also found to be more abundant in clearer offshore waters than in the more turbid waters of Bristol Bay. Copepods make up 70 to 90 per cent of the total Bering Sea zooplankton (Mednikou, 1960).

Characteristic species of Bering Sea zooplankton include copepods (*Calanus cristatus*, *C. tonsus*, and *Acartia clausi*); chaetognaths, and other forms similar to those in the Gulf of Alaska. Musienko (1963) reported many larval fish in the zooplankton biomass, including some forms of valuable commercial species.

Zooplankton of the Chukchi and Beaufort Seas generally include species from the Bering Sea. Water flow is north from the Bering Sea, such that English (1966) stated that the marine environment of the eastern Chukchi Sea is dominated by the flow of Pacific Ocean water moving through the Bering Strait. Several exceptions are the nearshore lagoon areas which exhibit freshwater or brackish--water zooplankton forms (Johnson, 1966). Johnson and Brinton (1963) report that several characteristically artic species occur in the Artic Ocean. The copepods, *Calanus hyperboreus*, *Metridia longa*, and *C. glacialis* are examples.

(3) Benthic Biota

Although relatively little information is available on benthos of Gulf of Alaska waters, studies have shown considerable differences in biomass, particularly between areas near land masses and from under central ocean gyres (Conney, 1972).

Semenov (1965) reported 108 species of benthic organisms from the continental shelf and upper slope of the Gulf of Alaska. The highest standing stocks (120 - 520 g /m^2; average of 180 g /m^2)occurred in rocky areas and those of gravel and pebbles. The other substrates had similar biomass estimates of 40 - 70 g /m^2. The continental slope average was 19 g/m^2.

Considerable variation was encountered due to depth, currents, substrate, and other factors. Strong currents appeared related to high biomass estimates.

Another study of benthic fauna on the continental shelf was completed by the National Marine Fisheries Service (undated). Large numbers of mussels, basketstars, sea pens, sea cucumbers, sea urchins, anemones, and starfish were commonly encountered forms.

The Bering Sea benthos also varies spatially. Niemann (1963) reported very low standing crop estimates for Bristol Bay (less than 10 g/m^2) but much higher ones over the continental shelf to the north of Bristol Bay (over 100 g/m^2). Semonov (1964) indicated most of the biomass consisted of polychaetes (worms), molluscs (clams), and echinoderms (sea cucumbers, starfish).

Gulland (1972) discussed the value of benthos as fish food. He concluded that although the Bering Sea biomass of benthos exceeds that of the Gulf of Alaska, the biomass of the latter area is about three times more useful as fish food than that of the Bering Sea.

The benthos of the Chukchi and Beaufort Seas are comparable in biomass and numerical density to temperate regions (Artic Institute of North America, 1974), in spite of a much more rigorous environment. Carey, et al. (1974) found annelids, molluscs, and arthopods, in that order, to be the dominant organisms. These authors found that the numerical density of organisms increased offshore, reaching a peak density at 700 meters (4,344 organisms /m^2). In contrast, the biomass was greatest (227 g/m^2) on the continental shelf at a depth of 140 meters and lowest at 700 meters (4.1 g/m^2). This implies that much larger organisms are found on the upper continental shelf than on the slope.

Quantitative studies of benthos of the Chukchi Sea off Siberia indicated a biomass of 25 - 30 g/m^2 at depths of 8 meters. In depths of 30 to 50 meters, the biomass averaged 214 g/m^2, with polychaetes being the dominant group (by weight) followed by arthopods and molluscs (Zenkevitch, 1963).

(4) Active Swimmers - Nekton

Alaskan waters harbor an immense number of active swimmers, including invertebrates, fish, mammals and diving waterfowl. The majority of information concerns commercial species of finfish and shellfish. These species include salmon, habibut, and, although not nekton, shrimp, king and tanner crabs. Other species, harvested principally by foreign fleets, are the herring, pollock and Pacific Ocean perch. Because of high costs of labor, materials, and services, Alaskan fisheries have concentrated on high unit value species such as those listed above. Consequently, other species of nekton have not been actively exploited or investigated.

The Arctic Ocean can generally be disregarded in terms of significant commercial fisheries because of the rigorous environment.

Salmon and herring are the two principal pelagic species harvested in both the Gulf of Alaska and the Bering Sea. Demersal fish (living on or near the bottom) make up a small proportion of the Alaskan catch. Table 25 illustrates the magnitude (and relative importance) of Alaska's fisheries from 1961 to 1969.

Each species of fish characteristically inhabits a specific environment, delineated by depth, currents, temperature, forage, and other factors. Therefore, estimates of fish abundance must include a description of the environment. Table 26 indicates the importance of depth in estimates of flatfish taken from the Gulf of Alaska, as well as representative fish species. Westerheim (1970) generalized that maximum catches of flatfish occurred in depths greater than 400 meters, but that the greatest variety of species was found in depths of less than 300 meters.

However, the impression that the Gulf of Alaska fish are limited to a few varieties of flatfish and salmon should not be made. Quast and Hall (1972) have reviewed Alaskan fishes in the Gulf, listing 25 fish families and over 100 species. Several species have been shown to be abundant and potentially able to support new fisheries, such as rockfish (Alverson et al., 1964) and the pelagic pomfret (Hitz and French, 1965).

Life history and distribution data for some of the more abundant species in the Gulf of Alaska has been summarized by (A.E.I. and D.C., 1974).

TABLE 25. Total Catches from the Northeast Pacific (Thousand Metric Tons)

Species		1961	1962	1963	1964	1965	1966	1967	1968	1969
Demersal fish	Alaska			14	11	15	14	12	6	10
Salmon	Total[a]	436	398	419	383	428	441	397	375	
	Alaska	120	126	101	142	125	152	63	130	100
Herring	USA	25	19	18	24	16	11	8	6	
	Alaska[b]			14	22	12	9	5	4	6
King Crab	USA	20	24	36	39	60	72	58	39	
	Alaska	20	24	36	39	61	72	59	37	26
Shrimp	USA	10	10	10	7	9	16	25	24	
	Alaska	7	8	7	4	8	13	18	19	22
Molluscs	Alaska									1

[a] Total North Pacific.

[b] Includes herring eggs on kelp.

SOURCE: Gulland, 1972.

TABLE 26

Pounds of Flatfish caught per hour of Exploratory trawling by Depth Intervals in the Alaska Peninsula Region (from Alverson, et al. 1964)

Species	Depth in Meters				
	1-90	90-181	182-272	273-364	365-547
threstes (Turbot)	26	137	541	992	698
itarichthys (Sand dab)	T	1	T	0	0
lytocephales (Rex sole)	1	4	34	26	120
ipoglossoides (Flathead sole)	21	80	145	31	2
sosetta (Butter sole)	6	1	T	T	0
eplopsetta (Rock sole)	159	46	3	0	0
imnda (Yellowfin sole)	13	8	0	0	0
icstomus (Dover sole)	T	1	6	29	87
arhrys (English sole)	T	T	0	0	0
lachthys (Starry flounder)	4	T	0	0	0
leonectes (Alaska Plaice)	1	T	T	0	0
leichthys (Sand sole)	1	T	0	0	0

(T = Trace)

Information on fish of the Bering Sea is dominated by Bristol Bay stockeye salmon. This salmon fishery is the largest in the world. However, several other species are taken in large quantities; halibut, herring, and a number of species of demersal fish (Gulland, 1972). A large proportion of these fish are taken by foreign vessels.

Table 27 lists the potential yeild of demersal fish stocks in the Bering Sea, as compared to the Gulf of Alaska. Assuming relative correctness of these estimates, the Bering Sea appears to be about three times more productive for these species than the Gulf of Alaska.

TABLE 27

Potential annual yields from the major demersal fish stocks (thousand metric tons). Adopted from Gulland (1972).

Species	Gulf of Alaska	Bering Sea
Yellow sole	1	180
Rock sole	15	110
Arrowtooth flounder	60	20
Flathead sole	20	20
Dover sole	10	0.5
Halibut	18	2
TOTAL	124	332
Pacific Ocean perch	50-70	14-21
Pacific hake	—	—
Alaska pollock	50	550
Pacific cod	30	40
Spiny dogfish	1	—
TOTAL	265	940

Demersal fish appear most abundant at depths less than 100 meters in the Bering Sea. Catches by commercial fishing fleets in this area indicate that most of these fish feed on the continental shelf during the summer and winter on the continental slope.

Fish of the Artic Ocean include both pelagic and demersal species. Adult pelagic species are represented by the Artic cod, Artic char, and the Pacific herring smelt. Demersal species are represented by Artic staghorn sculpin, hamecon, Bering flounder, and saffron cod (Alverson and Wilimovsky, 1966).

Arcticfish are very few in terms of species (about 69), although large populations of individual species may occur during the summer. The sparseness of fish is a function of such environmental factors as low temperatures, low primary productivity, and ice-scouring in the shallow littoral zones (Arctic Institute of North America, 1974). According to Alverson and Wilimovsky (1966), definite preferences or tolerances of these factors by Artic fish are apparent.

Marine mammals

Marine mammals comprise a conspicuous part of Alaska's marine fauna because of their numbers and relative size. Mammals occurring in Alaskan waters are classified in four major orders: Carnivora, Pinnipedia, Mysticeti, and Odontoceti. The carnivores are represented by the sea otter and polar bear, while the pinnipeds (seals, sea lions, and walruses) are represented by nine species. Whales, porpoises, and dolphins, collectively known as cetaceans, are divided into two orders; the odonicetes (toothed whales), and the mysticetes (baleen whales). There are at least 22 species of marine mammal species inhabiting the Gulf of Alaska region, 25 species in the Bering Sea Region, and 20 species in the Artic Ocean Region. Table 28 lists the species, area found, and population estimates.

Many of the marine mammal species that occur in Alaska waters are seasonal entrants and range in internation waters. Consequently, they are of concern and potential value to other nations. The Marine Mammal Protection Act of 1972 prohibits the harvest of marine mammals except for subsistence use by certain Alaskan routines, display, and scientific collections. A further exception is the fur seal harvest which is regulated by international treaty.

Sea otters are presently found from Yakutat Bay westward to Prince William Sound, the Kenai Peninsula, both sides of the Alaska Peninsula and Aleutian Islands, and St. George Island in the Bering Sea. Sea otter habitat consists of shallow coastal waters less than 75 meters deep. Typically, they are found along rocky coasts exposed to the open ocean, especially in the vicinity of offshore rocks and extensive kelp beds.

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Table 28

Occurrence of Marine Mammals in Alaska

s	North Pacific	Bering Sea	Arctic Ocean	Estimated Total Population
Bear	--	PR	PR	3,500
ter	PR	PR	--	125,000
Sea Lion	PR	PR	R	200,000
rn fur seal	SE	SE	R	1,200,000
seal	PR	PR	SE	100,000
seal	--	PR	PR	250,000
eal	--	--	A	——
seal	--	--	A	——
seal	--	PR	SE	90,000
l seal	--	PR	PR	300,000
walrus	--	PR	PR	130,000
hale	SE	SE	SE	11,000*
ale	SE	SE	SE	13,000*
ale	SE	SE	R	20,000*
whale	PR	SE	R	——
hale	SE	SE	--	——
Right whale	SE	SE	--	250*
k whale	SE	SE	SE	1,200*
l whale	--	PR	SE	2,000*
whale	SE	SE	--	150,000*
whale	PR	PR	SE	2,000*
whale	PR	SE	SE	——
Sea beaked	SE	SE	--	——
beaked whale	SE	SE	--	——
Bottlenose	SE	SE	--	——
inned pilot	SE	--		——
	--	--	R	——
rpoise	PR	SE	--	——
porpoise	PR	SE	R	——
sided dolphin	R	--	--	——
n Right-Whale hin	R	--	--	——

- Rare
- Accidental
- Seasonal Entrant
- Permanent Resident

*Whale populations include entire North Pacific Ocean.

: USDI, 1973; Nishiwaki, 1967; Brooks, 1971; Scheffer, 1972; Burns and Morrow, 1973; Berzin and Rovnin, 1966; A.D.F. and G., 1973.

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Kenyon (1969) estimated the world population of sea otters in 1965 to be about 33,000, with Alaska accounting for about 26,500. In 1973 the Alaska Department of Fish and Game (1973) reported a maximum of about 125,000 sea otters in Alaska, 40,000 in the western Gulf, and 70,000 in the Aleutian Islands.

The diet of sea otters consists largely of echinoderms (especially sea urchins) and molluscs. Frey (1971) indicates that fish also made up a part of the diet. Food is always consumed in the water by sea otters, never on land.

Otters give birth to a single pup every other year. Infant mortalility is low, even during harsh winters. Gestation is about 13 months (Kenyon, 1969). Otters weigh from about 50 pounds (females) to 75 pounds (males) and may live for 15 or 20 years (Frey, 1971).

Polar bears are associated with the ice edge and consequently these animals move north and south seasonally. They are found throughout the Bering Strait, and the Chukchi and Beaufort Seas. Brooks (1971) indicates that there are two distinct populations of bears in Alaska, one in the Chukchi Sea and the other in the Artic Ocean. Brooks also estimates the number of bears in Alaska to be about 3,500 animals.

The primary food items of the polar bear are the bearded and ringed seals, although other wildlife and carrion are taken at will.

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Females breed once every three years. Cubs (usually one or two) are born in winter, weighing about one pound. The mother continues her association with the cubs for about 2½ years before breeding again.

The pinnipeds (with the exception of the walrus) are common inhabitants of the littoral zone above the continental shelf. Sea lions generally prefer the more southern regions of Alaska, such as the Gulf and the Aleutian Islands, while harbor seals, fur seals, ringed seals and bearded seals prefer the northern waters of the Bering Sea and Artic Ocean. The latter two migrate seasonally with the advance and retreat of the ice. Sea lions, harbor seals and fur seals are associated with offshore rocks and land for hauling (resting) and breeding.

The northern fur seal supports a considerable commercial enterprise based on its pelt. Management is shared by several nations. Its main breeding grounds are the Pribilof Islands, west of Nome, where they are harvested (Baker, et al., 1970). Between 40,000 and 50,000 fur seals are taken annually, for a gross income of about 3½ million dollars (Kenyon, 1971).

The Pacific walrus occurs seasonally in the Artic Ocean, generally concentrated west of Barrow in the Chukchi Sea, and occasionally in the Beaufort Sea. They winter almost entirely in the Bering Sea and migrate back to the Artic Ocean in the spring. About 130,000 walrus inhabit Alaskan waters.

Their diet consists primarily of molluscs and their location is generally determined by the location of extensive clam beds. Food sources for walrus are much more restricted than for other pinnipeds (A.D.F. and G., 1973).

The Mysticeti, or baleen whales, are those whales with baleen plates in their mouths which are used to strain plankton and other food from seawater. These whales undergo extensive migrations, often traveling to the western shores of Mexico during the winter months. This migratory nature has made these mammals vulnerable to exploitation from many nations. Consequently, stocks of the larger whales have been severely depleted by whales. As the larger whales have become more scarce, the smaller whales have become subject to exploitation as well..

Management of whale stocks depends on population parameters such as birth and death rates, and stock size. This information is difficult to obtain, as is concensus between exploiting nations regarding conservation. As a result, whale populations continue to be stressed. (See also the section on Endangered and Threatened Fish and Wildlife).

Odontoceti, or toothed whales, include porpoises, killer whales, beluga whales, and sperm whales. The sperm whales are the largest of the toothed whales and are subject to exploitation as discussed above. Their principal food item is squid. Killer whales are the

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ost widely distributed marine mammal in the world (Nishiwaki, 1967), nhabiting all oceans in the northern and southern hemispheres. rince William Sound is an area of concentration for killer whales, here they feed on fish, seals, and sea lions (Scheffer, 1972).

he beluga whale ranges throughout Alaskan waters from the Gulf o the Arctic Ocean. They enter estuaries and rivers in the summer, onsuming fish, crustaceans, and squid from the bottom waters.

he porpoises are very common in Alaskan waters, particularly in ummer months. Harbor seals are more common inshore, while Dall's orpoises are more common in offshore waters. There is no commercial xploitation of these mammals except for a very few for exhibition. hey are sometimes eliminated by fishermen when found in their almon nets. Principal items in the diet are squid and fish Mizue, et al., 1966).

(5) Coastal and Marine Birds

The avifauna of the offshore and coastal regions of Alaska is notably varied and abundant. Many of the seabirds, shorebirds, and water fowl that breed in or migrate across offshore and coastal regions of Alaska originate from trans-Pacific or trans-equatorial regions. Thus Alaska's bird resources are a national and international resource of considerable value and concern to many nations. Seabirds and waterfowl provide food for subsistence and commerce, others provide recreational opportunities, and all are aesthetically and ecologically valuable (Bartonek and Sowl, 1972).

Birds are recognized as an important part of the marine ecosystem. Birds transfer, concentrate and recycle nutrients and energy between trophic levels, as well as within and/or between regions. Birds droppings are considered an important source of phosphates and nitrates which help support plankton production, and utimately, regional fisheries (Ainley, 1974).

Birds that inhabit coastal and offshore waters of Alaska have been treated, in varying degrees and oceanographic ranges, in several works. Gabrielson and Lincoln (1959) summarized the early accounts of bird observations in Alaska. Sanger (1972) estimated the numbers and biomass of seabirds in the subartic Pacific region, and King and Lensink (1971) reported on an evaluation of migrating bird habitat in Alaska.

At least 8 families, 27 genera, and 59 species of pelogic birds occur in the offshore waters of Alaska. This does not include the more coastal birds such as loons, grebes, several species of shorebirds, ducks, geese, and swans. The estimated total standing stock of seabirds (excluding the Artic Ocean) is about 37.2 million (Sanger, 1972). The average densities tend to be highest in the coastal regions. Summer densities are much higher than in winter. Highest summer standing stock was found in the central Gulf of Alaska, perhaps because of its large size.

At least 208 species of birds are known to occur in northern Gulf of Alaska and Prince William Sound. Of these, 128 are regarded as being primarily water-oriented. There are 121 species occurring mainly in the spring, 100 in the summer, 108 in the fall, and 71 in the winter. About 60 species of water-oriented birds are considered permanent residents in the Northern Gulf (Kessel, 1972). Small alcids dominate standing stocks in winter. In summer, the stocks are dominated by shearwaters and fulmars.

Specific areas that are of critical importance to birds in the northern Gulf area are sea cliffs that border the mainland and offshore islands, tide flats in Orca Inlet, wetlands in the Copper River Delta, and pelagic foraging areas off the Copper River Delta.

Sea cliffs provide nesting and resting habitat for a variety of seabird species. There are about 110 major seabird colonies in the northern Gulf, inhabited by an estimated one million birds during the breeding season.

Portions of the coastline, offshore islands and waters, estuaries and river deltas in the northern Gulf provide habitat for vast numbers of birds. There are about 2.2 million seabirds in the coastal area during winter and 10.6 million during summer (Sanger, 1972). Bartonek and Sowl (1972) estimated the numbers of seabirds in the Gulf of Alaska alone at about 9 million. Nearly 150,000 black brant and 250,000 cackling Canada geese migrate directly across the Gulf of Alaska between the Alaska Peninsula and British Columbia. Nearly the entire North American breeding population of 12,000 dusky Canada geese breed in the Cooper River Delta each spring (Chapman, 1969). Fall flights have ranged from 20,000 to 42,000 duskies. The delta also attracts about 10,000 snow geese in the fall (ADF & G, 1973). About 10,000 Canada geese and 10,000 snow geese inhabit the Yakutat area.

Over 100 species of birds have been observed in the Cook Inlet area. Wetlands along the periphery of the Inlet are particularly important to waterfowl during spring and fall migrations. Of the seabird colonies in Cook Inlet (about 20) the most important are the Barren Islands, where more than 400,000 birds breed.

Almost the entire world population of emperor geese (about 100,000) winter in the Aleutians and the southwest Gulf of Alaska, where they frequent coastal lagoons and bays. Hundreds of thousands of ducks and geese occur in the area, notably black brant and emperor geese. The black brant population of the Pacific flyway is often characterized as staging entirely in Izembek Lagoon on the northside of the Alaska Penisula and then leaving en masse.

A total of 183 species of birds have been recorded in the Aleutian Islands and adjacent waters. Fifty-four species of birds breed on the Aleutian Islands National Wildlife Refuge while 75 species are common migrants and 55 are casual or accidental species (Sekora, 1973). Estimates indicate a minimum breeding population of four million pelagic birds in the Aleutian Refuge.

Bristol Bay serves as a crossroads for waterfowl from many other countries. Large eelgrass and saltwater lagoons in Bristol Bay, as well as the numerous ponds and lakes, constitute the region's most important waterfowl habitats. They are used primarily as resting and feeding areas during migration. In spring and fall, as many as 32,000 black brant, 10,000 Canada geese, 60,000 emperor geese, 5,000 pintails and scaup, and 100,000 eiders have been observed in Chagvan and Nanvok Bays, but these are only part of a transient population that uses the area. In addition, several million sea birds nest along coastal cliffs.

More than half of the 352 species of birds recorded in Alaska have been recorded in the Seward Peninsula - Kotzebue - Selawik region (USDI, 1973b; 1973d). At least 109 are nesting migrants, about 15 are nesting residents, and about 41 probably occur as non-breeding migrants and vagrants. About 32 seabird colonies are found along the northwest Alaskan coastline. For example, seabirds resting along the rocky sea cliffs are the most conspicuous element of the avifauna in the Cape Thompson and Cape Lisburne area. Five seabird colonies in this area exceeded 420,000 breeding birds in 1960. Murres were by far the most abundant seabird species numbering almost 400,000 (USDI, 1973b).

Although the Chukchi seabird population is neither large nor concentrated, the area is an important migratory pathway in the Asiatic - Pacific flyway (Watson and Divoky, 1972). The bird fauna of the offshore waters of the Chukchi Sea is considerably richer than that of the Beaufort Sea, particularly with regards to murrelets, auklets, and puffins.

Migratory waterfowl of the Beaufort Sea travel all the continental flyways and several international flyways. The arctic coastal plain and offshore islands support an estimated spring breeding population of about 500,000 ducks, geese, and swans (Montgomery and Boughton, 1974). Sea ducks, phalaropes, and gulls are the most numerous birds in the Bering Sea. Also present in large numbers are loons, jaegers, alcids, and arctic terns. Bird distribution is generally limited to within 35 miles of shore (Bartelo, 1973). Of particular importance is the migration route along the coast. The king eider migration alone has been estimated at one million birds passing Point Barrow. Two-thirds of the avifauna of the Canadian arctic islands pass along the Beaufort Sea coast.

Oldsquaw numbers on the Arctic slope reach 400,000 birds on the beach at one time. However, many more pass through the area during the summer. Almost all common eiders nest on offshore islands along the coast. Brant concentrate their nesting activity on the islands of the river deltas. The only known nesting area for snow geese in the United States is on an island of the Sagavanirktok River Delta.

Although waterfowl can be found throughout the Beaufort Sea Region, the area within five miles of the coast (the Barrier Islands) accounts for the greatest number. These islands stop the pack ice when it drifts toward the shore and ameliorate the winds, providing a shallow, sheltered, ice-free area for feeding, nesting, and molting. This area is obviously of critical importance to birdlife (Montgomery and Boughton, 1974).

Frame (1973) noted birds were more abundant within 50 miles of land where ice was thinner and open leads (cracks in the ice) more common. Plankton, molluscs, and small fish in the Beaufort Sea during summer provide a rich feeding ground for seabirds.

(6) Unique Environments

"Unique" environments in Alaska are considered to be those habitats which are critical to the existence of certain fish and wildlife populations or those areas where uniquely abundant fish and wildlife populations occur.

Isolated rocks, islets and rocky points along the mainland and offshore islands are used by vast numbers of seals or sea lions for breeding rookeries or hauling grounds, and could be considered unique environments. There are about 202 known sea lion rookeries along the Alaskan coast. The Pribilof Islands are the only northern fur seal breeding areas in the United States; about 1.2 million fur seals congregate on the Pribilofs each spring to breed. The several islands in the Bering Sea, which are the only American walrus hauling grounds, could also be considered unique.

All existing and proposed Alaskan coastal wildlife refuges should be considered unique environments since that was the very reason they were designated as such.

Alaska's Gulf coast region, Aleutian Islands, offshore islands and mainland promontories of the Bering Sea provide resting and nesting habitat for a vast number and variety of seabird species; therefore, the approximately 250 seabird colonies in Alaska and the several million seabirds they support are considered unique environments. Buldir Island in the western Aleutian Islands should be considered unique since that is where the entire world's population (200 to 300 of the endangered Aleutian Canada goose breeds. Izembek Lagoon,

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cated on the north side of the Alaska Peninsula, is the staging area r the entire world's population of black brant (150,000), cackling ese (150,000), and emperor geese. Izembek Lagoon also contains the rgest known eelgrass beds in the world.

arly the entire population of emperor and cackling geese and half e continental population of black brant nest in a narrow zone of astal habitat in the Yukon Delta. The entire Pacific flyway pulations of white-fronted geese and most of the Pacific flyway istling swans also nest on the Yukon Delta. The entire North erican breeding population of about 12,000 dusky Canada geese eed only in the Copper River Delta area adjacent to the northern lf of Alaska.

proaches (bays) to all anadromous fish streams should be considered ique environments. Waters adjacent to anadromous streams provide bsistence and protection to young fish as they adjust to the rine environment. This transition period from fresh to salt water one of the most critical periods in the life of young anadromous fish.

e. Natural Phenomena Unique to Area with Potential to Cause or Contribute to Environmental Impacts of Proposed Action

A wide range of environmental and geologic problems may be experienced in Alaska. Phenomena of major importance in the southern portions of the state are earthquake activity, potential fault offset, volcanic activity, mountainous terrain, high waves and sgrong winds. In the northern portions of the state, problems regarding sea ice movement and permafrost predominate. Geologic phenomena have been discussed in the Geology section, while winds and waves have been discussed under Climate and Physical Oceanography, respectively.

Ice can cause or contribute to environmental impacts throughout Alaskan waters, but impacts are generally north of the Aleutian Islands which act as a barrier to southern extensions of winter ice cover. Ice can form on fixed structures and ship's superstructures, thus increasing the mechanical stresses. Ice also presents a potential hazard to fixed structures due to collisions of ice propelled by tidal currents. A similar hazard is present when icebergs or bits occur in navigation routes. Such conditions may occur in Cook Inlet, Bristol Bay and all waters to the north, as well as nearshore areas from Prince William Sound to Juneau.

Pack ice in all waters north of the Aleutian Islands poses a hazard to fixed structures because the ice cover moves great distances. Once in motion the ice has tremendous force. When it encounters the coastline, ice blocks are thrust up on the beach, scouring and gouging the beach and adjacent sea bottom. This action has been reported to occur in depths of 90 to 150 feet on the outer continental shelf. Scour widths of 100 to 200 feet, lengths of 2 to 3 miles, and scour relief of 30 feet have also been noted (A.I. of N.A., 1974).

Glaciers, another form of ice, have been known to surge, or advance rapidly (Swift, et al., 1974). The cause of glacier surges are unknown and therefore are unpredictable in time.

Another natural phenomenan which may cause environmental impact is severe seasonal flooding. The hazard is greatest in southeastern Alaska where mountains with huge snow fields and glaciers skirt the Gulf of Alaska. Past and Mayo (1971) discuss the floods caused when water is released from ice-dammed lakes and rivers.

B. Description of Nearshore and Coastal Zone Environment

1. Atlantic Region (and Sub-Areas)

a. Geology

The geology of the nearshore and coastal zone has been described in the discussion of the offshore environment (section II A 1 a). This was done to present a complete and continuous description. Unlike biological and some physical parameters, geologic structures are not commonly distinguished according to an arbitrary division based on water depth or proximity to the shoreline. Where specific geologic structures are unique to a nearshore area, they are noted as such.

b. Biological Environment and Communities of the Coastal Zone

The Atlantic coastline extends 5,565 miles and can be ivided into several distinct physiographic regions. The area from the lorida Keys to the Cape Fear River in North Carolina can best be ategorized as a smooth coastline, occasionally indented with estuaries nd embayments; with a series of barrier islands. These barrier islands e sandy dunes which are constantly moving landward. Estuarine ponds or unds are common between these islands and the mainland. The most ominent barrier island system occurs off the mainland of North Carolina. e "Outer Banks" extend from just north of the Cape Fear River to the rginia-North Carolina Border. The Pamlico and Albemarle Sound system mprise the largest estuarine lagoon along the Atlantic Coast.

pe Hatteras marks the southern boundary of the embayed section of the lantic coast. This section is characterized by large indentations mbayments, estuaries, and ponds) and extends northward to Cape Cod. e majority of these estuaries result from drowned river valleys, but, e Long Island Sound was enclosed by large coastal structures which have en covered by glacial deposits. Other emergent structures of similar igin include Cape Cod, Martha's Vineyard, Long Island, Block Island l Nantucket Island. The well known bays in this area include the esapeake, Delaware, and Narragansett Bays. The coastline north of Cape l is irregular, with exposed rocky headlands and unconsolidated beaches erspersed.

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The description of nearshore and onshore biology is categorized by community type for the sake of brief discussion. Further the discussion of community types is limited to those types which might be affected by oil beaching as a result of accidental discharge.

(1) Benthic Algae

Benthic algae, including diatoms and macrophytes figure prominantly in the energy flow of the nearshore community throughout the area. Artificial hard substrates such as pilings and rocks structures as well as silty and sandy substrates are colonized by these benthic algae. Pomeroy (1959, in VIMS, 1974) estimated that the productivity of these flora in a Georgia marsh averaged 180-200 g $C/m^2/yr.$ for the diatoms and as high as 320 g $C/m^2/yr.$ for non-diatomaceous species. A total of 239 species of macrophytes have been identified in the State of North Carolina alone (VIMS, 1974). Grazing, relative exposure, light levels and availability of suitable substrate are significant factors in the occurrence and population levels of benthic macrophytes. *Porphyra*, *Enteromorphos*, *Ulva*, *Calothrix* and *Chaetamorpha* are dominant shallow water species. Humm (1969) hypothesized that all oceanic algae along the Atlantic coastline have resulted from two geographic populations, one of tropical origin with its north boundary at Cape Canaveral, the other originating in the northwest Atlantic with Cape Cod as its southern boundary. The resultant algae populations in the Central Atlantic region are comprised of eurythermal (capable of tolerating a wide range of temperature) species of both regions.

o natural intertidal rock has been identified in the Central Atlantic egion. Artifically placed hard substrates and naturally occurring ounds, inlets, beaches, offshore reefs, and muddy beaches offer suitable abitat for benthic algae. Supratidal zones are colonized by Calothrix, ntrophysalis and Plectonema (URI, 1974). The intertidal zone is requented by Porphyra, Ulva, Enteromorphos, and Fucus predominantly. ladophora, Codium, and several other genera are represented on muddy ntertidal substrates. The more common general subtidal algae in the entral and South Atlantic regions include Bryopsis, Sargassum, Ulva, ladophora, and Enteromorpha.

earce and Williams (1951, in URI, 1974) described five types of algal mmunities based upon salinities: 1) brackish, primarily salt marshes ere dominated by Herposiphonia, Caloglossa, and Bostrychia; 2) estuarine ter dominants were Ulva and Graciloria; 3) estuarine waters between and 32°/oo were dominated by Sargassum, Codium, and others; 4) rocky eanic coasts contained the predominants Ulva, Enteromorpha, and lidium; 5) offshore submerged oceanic reefs are dominated by rgassum, Pocockella, Spatoglossum, Cladophora and others.

ntucket Shoals-Cape Cod represents a sharp boundary of benthic algae ganisms. The cold waters of the Laborador Current are found north this boundary, and warmer waters with partial origins from the

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Gulf Stream prevail to the south. There is overlap with several more eurythermal species found occasionally on either side.

Taylor (1957, in TRIGOM, 1974) has described ten grown and nine red species of algae north of Cape Cod. The distribution of eurythermal species between Long Island and the Gulf of Maine is complex and will not be described here. The kelp *Laminaria*, and the brown algae *Ascophyllum* and *Fucus* typically can be found on hard submerged substrates from Long Island and northward.

(2) Submerged Seagrasses

Seagrasses form an important part of the benthic community wherever they occur. They serve as: 1) necessary hard substrate for benthic organisms, 2) major food sources, 3) shelter for organisms and occasionally abate high wave energy, 4) provide detrital food for estuarine and nearshore organisms, 5) stabilize and aid in bottom deposition by abating bottom currents (VIMS, 1974).

Eel grass, *Zostera marina* occurs throughout the Atlantic coastline from Beaufort, North Carolina northward. *Zostera* represents a warm season species and is replaced in cooler seasons by *Holodule beaudittei*. Turtle grass (*Thalassia testudinum*) and Manatee grass (*Syringodium filiforne*) are predominant grasses south of Cape Canaveral but do not extend north of this physiographic feature. Widgeon grass (*Ruppia marina*) is a widespread low salinity species. Potomogetan spp. are found in freshwater areas which are occasionally flooded with saline water.

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Zostera marina, *Potomogeton* spp. and *Ruppia* are common throughout the Central and North Atlantic regions, primarily in embayments and sheltered waters.

(3) Mangrove Swamp Systems

Mangrove swamps comprise an important shoreline community south of Cape Hatteras. The Cape marks its northern boundary with few isolated mangrove beaches occurring to the north. One continuous beach stand of mangroves covers approximately 675 square miles in south Florida. Three species are common: red mangrove, *Rhizophora mangle*; black mangrove, *Avicennia gerimans*; white mangrove, *Laguncularia racemosa*. The red mangrove is commonly found on the seaward side of the community with black mangrove occurring on tidally flooded flats just inshore. The white mangrove is found throughout both of these regions. The predominant physical factor which limits the northern spread of the mangrove is temperature. Hard frosts are invariably fatal. Regular tidal flooding is also necessary to maintain the mangrove forest stands. Mangrove communities contain a wide variety of algae and fiddler crabs. Barnacles, oysters, snails, turtles, crocodiles, bears, wildcats, pumas and rats all are occasionally found in this habitat (Kuenzler, 1974). The productivity of mangrove stands have been estimated to be equal to that of good farm land.

Mangrove swamps are valuable in their ability to abate and absorb wave energy during storms and hurricanes. This aspect is particularly important during hurricanes when the sea level is elevated due to storm surge. Menhaden, mullet, spotted sea trout, snook, tarpon, red drum, pink shrimp and other species utilize these swamps as nursery grounds. Oysters commonly occur in marketable quantities in these areas. Eighty-nine species of aquatic birds, as well as manatees, otters, crocodiles and alligators can be found in these swamps. The mangrove community has sustained loss of over 75% of its original area due to man's activity. Normal cutting, dredging, and filling have been responsible for this loss.

(4) Rocky Sea Fronts

The primary physical factors which govern biotic zonation in this type of habitat are; availability of rocky substrate, intermittent exposure to air, and breaking waves. The flowing sea water enriches the environment by washing in nutrients and oxygen and carrying out metabolic waste. Algae, mussels, limpets, chitons, and urchins are characteristic of this habitat (Odum, et al., 1974). The naturally occurring rocky beach is restricted to the North Atlantic region where large tidal fluctuations (6 meters or more) commonly occur. Heavy beds of predominantly brown algae, mussel beds, and carnivores such as starfishes, lobsters, and crabs are common. The shallow zone

[redacted]

of this habitat is colonized by barnacles, diatoms, blue-green algae, oysters, periwinkles, and other organisms capable of withstanding regular periods of air exposure. Below this zone can be found macrophytes (large plants), mussels, oysters, and herbivorous molluscs. Productivity is lower in the cooler seasons than in summer and fall. Most macrophytes are long-lived, thus species do not change seasonally but dominance from season to season does change.

(5) High Energy Beaches

This type of habitat is characterized by sandy and sand-gravel substrates, and breaking waves. High energy sandy beaches comprise most of the Atlantic coastline south of Cape Cod. Specialized organisms found along these beaches have been termed psammon (Riedel and McMahan, 1974). Epipsammon (which live above the sand substrate) include birds, fish, and beetles. Mesopsammon (which live between the sand grains) include copepods, amphipods, and others. Organisms which live below the sand (endopsammon) include crustaceans, bivalves, and snails. Filter-feeding predominates in this type of a habitat. Organisms which are common in the surf and wash zone possess the ability to burrow rapidly into the sand. One of the most common Atlantic coast examples of this adaptation is the mole crab, _Emerita talpoida_. The surface configuration of high energy sandy beaches may be altered by the erosion of storm waves, changing the substrate type as well as the

[redacted] [redacted]

beach topography. Storm induced erosion may alter the biotic community along a specific area for a period of months to years.

(6) Barrier Beaches.

Barrier beaches, as has been described in a previous chapter, extend over the majority of the Atlantic coastline south of Cape Cod. These beaches normally are made up of sandy substrate and possess sand dunes and marshes. Salt marshes normally occur behind a series of dunes, and border on salt water lagoons which separate the beaches from the mainland. The beach and dune system receives sand from wave transport on the seaward edge and is continually moving landward. This progression results in a succession of habitat types behind the dunes.

Man has attempted to stabilize these dunes with snowfences and artifical plantings of dune grasses. These efforts have resulted in the erosion of the beach and ultimate erosion of the foredune system (normally a continuous dune closest to the surf zone). This stabilization has resulted in a typical dune community growth as will be described below.

Zonation on the barrier beaches is relatively consistent throughout the Central and Southern Atlantic region. The two dominant grasses in pioneer zone (the vegetated zone closest to the surf) are; the sea oat (_Uniola paniculata_) and the saltmeadow cordgrass (_Spartina patens_).

[redacted]

Both of these plants are capable of resisting the effects of salt spray, abrasion by wind-borne sand, and partial burial by sand. A grassland zone occurs immediately behind the pioneer zone and is characterized by nearly pure stands of Spartina patens. Juncus roemerionus occurs in nearly pure stands inshore of the Spartina. A salt marsh normally occurs behind this zone which is characterized by Spartina alterniflora (VIMS, 1974). Larger barrier beach systems may contain a scrub zone and a maritime forest zone. The scrub zone is characterized by the marsh elder (Iva), the salt myrtle Baccharis, and the wax myrtle Myrica. These organisms occur in the zone sheltered from salt spray by the foredune. The maritime forest is primarily made up of live oak Quercus virginiana, the scrub oak Q. myrtifolia, the slash pine Pinus caribaea and others. The incidence of wind-borne salt spray primarily limits the areal coverage of this type of community. This zone is well above the height reached by sea water under normal or severe storm conditions.

The plant sea rocket Cakile edentula, the croton Croton punctalus, and the ground cherry Physalis maritima occur between the pioneer and the grassland zones on unmodified dunes but are absent on dunes which have been stabilized (URI, 1974). Stabilized dunes are colonized by the dominant seagrass Amophila breviligulata from North Carolina north. Amophila has been planted as part of many stabilization attempts. Juncus spp. (rushes), Typha, and the bullrushes in the Central Atlantic

Region. Storm generated waves have breached the barrier island system repeatedly, causing wave overwash across the islands into the marshes behind them. This phenomenon results in disruption of the normal community and may require several years for significant recolonization. The salt mashes are generally dominated by Spartina alterniflora, S. patens, and Juncus gerardi.

The above description holds for the entire Atlantic coastline where barrier beaches occur.

Barrier beaches supply extensive food sources and breeding areas for many shore and sea birds. The Atlantic Flyway, one of the major waterfowl migratory routes, runs along these Atlantic beaches. Seasonal populations of these waterfowl can reach as high as hundreds of birds per acre.

(7) Salt marshes

The salt marsh type of habitat occurs on unconsolidated sediment which is regularly flooded by tidal action. Normally, deep channels are maintained throughout the marsh by tidal currents. Figure 108 presents normal plant zonation within the marsh. The primary factor governing vegetation distribution is elevation. Practically pure stands of Spartina alterniflora are found in the lower levels of the marsh where tidal flooding occurs twice daily. The height of the S. alterniflora varies inversely with the elevation within the tidal zone. Salicornia and Distichlis may also occur at this elevation. Juncus

[redacted]

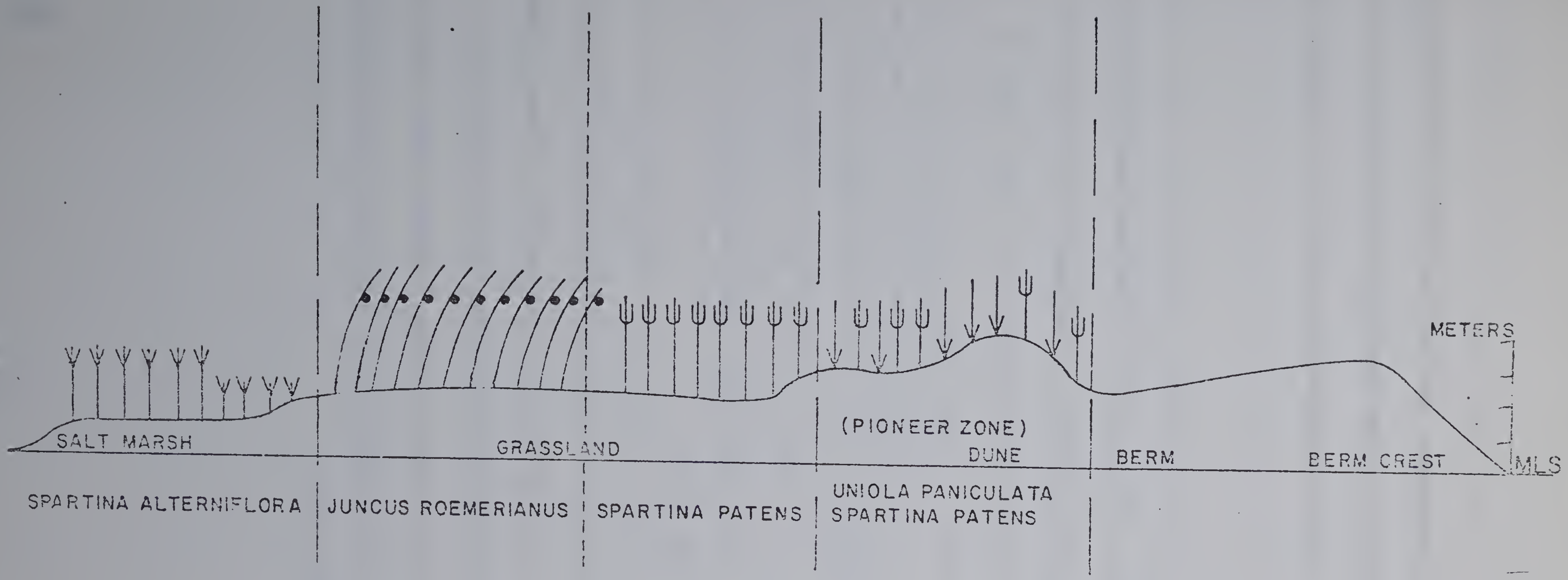

FIGURE 108. Vegetational zonation of sand dunes and marshes on Core Banks, Ocean to right, Core Sound to left (after Godfrey, 1970, from VIMS, 1974) roemerianus is the dominant organism at the high tide level. Spartina patens is the dominant organism in the next higher elevation followed by the scrub and maritime forest zones as described in the Barrier Beach section (Cooper, 1974).

Silt is constantly trapped due to slowing of current, and plant detritus is exported on the ebb tide. This detritus forms an important food source throughout the estuarine portion of embayments and along the coastline. Salt marshes exhibit productivity on the same order as fertile cultivated land systems. Major natural stresses in the marsh system are due to variations in salinity, temperature, and dissolved oxygen. Salinities vary annually from 1-28^{o}/oo and temperatures car show a 10^{o}C. daily variation, and an annual variaton from -0.5^{o}C. to 30.5^{o}C. Ice scour and summer desication have caused mass mortalities in the North Atlantic region (TRIGOM, 1974).

Man is constantly altering the salt marshes, with dredging, filling, spraying with pesticides, and dumping. The salt marsh community receives agricultural runoff. These effluents are heavy in pesticides and nutrients from fertilizers and animal wastes. Animals within the salt marsh food web have shown the capability of concentrating these pesticides to stressful levels (TRIGOM, 1974).

[redacted]

Repeated exposure to oil may have lethal results on *Spartina*, as was shown by a Bunker C spill in Chedabucto Bay, Nova Scotia. Heavy initial oiling, and repeated leaching caused extensive mass mortalities. Residence time for the oil in sediments was predicted to exceed 3 years with recovery requiring more time (Council on Environmental Quality, 1974).

Many fish utilize the marshes as breeding and nursery grounds. A listing of the more common such organisms is given in the *Active Swimmers- Nekton* section.

(8) The Oyster-Mussel Reef

Aggregations of oysters *Crassostrea virginica* and mussels *Mytilus edulis* are typical of the Atlantic coast. Oysters are rare north of Cape Cod, however. Oysters show marked preference for the setting of their larvae upon their own shell, which leads to the formation of large aggregates. This reef building may cause extensive alterations of local currents, substrates, and deposition of pseudofeces (indigestible particles filtered from the water). The surfaces of the oyster and mussel shells offer clean hard substrates to epibenthic organisms which would not be present if only unconsolidated substrate were available. These organisms include algae, hydroids, barnacles, mussels, polychaetes, and a number of boring sponges, molluscs, and

and worms. Salinity, temperature, and desiccation are the primary physical factors which govern distribution of these communities. Mussels and oysters filter plankton and detritus from the water. This type of community is presently stressed by a disease (MSX as described in Andrews, 1966) which has caused mass mortalities along the coast. Further, a significant number of these areas have been closed to commercial fishing because these organisms concentrate bacteria, present in human sewage outfalls, to health hazard levels. Because these organisms are sessile (they cannot move across the bottom) and are filter feeders, they are susceptible to high turbidity caused in part by dredging and filling. Large transplanting programs are underway to establish reefs in areas where they have naturally occurred in the past. Their success coupled with a gradual increase in resistance to the widespread disease described above have yielded slowly increasing catches in the last several years. Pesticides, hydrocarbons, and heavy metals all can be concentrated by the oyster. Thus pollution is presently stressing these commercially important communities along the Atlantic coast.

(9) Worm and Clam Flats

Large expanses of intertidal and subtidal mud flats extend along the Atlantic coastline. Temperature, salinity, tidal flushing, degree of exposure during the normal tidal cycle, and substrate all influence the distribution of this type of community. The number of species occurring in this type of community is often quite large due to the availability of high levels of nutrients borne by tidal waters and land-runoff. The numbers of benthic organisms may be as high as 355,000 per square meter (Odum, 1974). The preferred habitat for this type of community is a low energy, unconsolidated sediment between intertidal elevation and 20 meters water depth. These communities are most productive where active deposition of both silt and organic detritus occur, and where protection against active surf is provided by headlands, spits or barrier beaches. Plankton are the main primary producers in this community type. These communities are actively fished and evaluations of their economic value can be based upon a $2,900 to $3,750 per acre commercial annual yield. The major natural stresses affecting this type of community include severe temperature and salinity fluctuations and shifting sediments due to abnormal weather or sea conditions. A report of the effects of Bunker C oiling on a community of this type in Chedabucto Bay, Nova Scotia was presented by TRIGOM (1974). Heavy oiling resulted from a large spill and caused mass mortality of major commercially fished species associated with this community. Mya arenaria (soft shelf clam), Placopecten magellanecus (scallop) and other filter feeders and grazers were able to ingest and assimilate the oil. Oil did not appear to have been concentrated within the food chain. Homarus americanus (lobster) and Cancer irroratus (crab) showed low concentrations. Persistence of this oil, which became incorporated in the sediments, is still inhibiting recovery of the clam fisheries after three years. The long term effects of this spill is presently being studied by personnel of the Maine Department of Marine Resources and BLM.

(10) Salt Ponds

Salt ponds are small shallow embayments separated from the sea by barrier beaches. These ponds most commonly occur in the North Atlantic region. Limited connection with coastal waters is normally maintained by an inlet. Salt ponds are generally shallow and light penetrates to the bottom allowing high primary productivity. Nutrient input occurs from freshwater runoff, ground seepage, river outflow, and salt water moving through the inlet. These ponds are heavily used by migrating birds, and as nesting areas for many resident shorebirds and ducks.

Circulation within these ponds is sluggish and thus flushing time may be considerable. Eel grass Zostera marina usually is the dominant macrophyte in these ponds. Detritus from Spartina also constitutes a major food source for this type of community. Estimates of organic carbon produced in these salt ponds indicate a high productivity (265-275 grams carbon per square meter per year) (TRIGOM, 1974).

[redacted] [redacted]

Major natural stresses which affect salt ponds include variations in salinity and temperature, scouring by winter ice, shifting of sediments, and closing of inlets by longshore sediment transport.

Salt ponds are particularly susceptible to man-induced pollution because of their proximity to heavily populated areas, their slow flushing times, and their ability to trap nutrients and pollutants. They receive marine-borne pollutants from tidal interchange, and from agricultural pollutants and sewage from freshwater runoff. One pond type community that has received heavy loads of sewage effluent is Moriches Bay on the south shore of Long Island. A commercial oyster fishery was well established in Moriches Bay prior to heavy sewage loading. The high nutrient levels due to the effluent favored the algae domination by two diatoms *Nanochloris* and *Stichococcus* which are unsuitable for oyster food. The change in dominant plankton and the high BOD (Biological Oxygen Demand) due to the sewage effluent have resulted in the virtual destruction of oyster beds in Moriches Bay. Dredging of the pond inlets also significantly affects population levels and distribution primarily by altering the salinity regime and flushing time. Clams, oysters, and mussels are the primary commercial species associated with this community type.

(11) Plankton Based Pelagic-Estuarine System

An estuary is defined as a semi-enclosed body of water in which seawater is measurably diluted by freshwater. The estuarine environment is generally described by its salinity content (0.5%-30.0%) which may vary because of seasonal conditions or short term weather anomalies (heavy rains, droughts, etc.). Estuaries are rich in nutrients borne principally by the freshwater input and exhibit high primary and secondary productivity. The estuary also supports a high diversity of animals. Freshwater biota, oceanic biota, and biota peculiar to the mixing region of intermediate salinities occur in the estuarine habitat.

The major taxonomic groups of organisms which commonly comprise this type of community include phytoplankton, zooplankton, fishes, birds, and mammals. Temperatures may vary widely within a given estuary during normal seasonal changes. Short term anomalies in temperature are common as a result of storm activity. Nutrients and pollutants are introduced into the estuary by river runoff and intrusions of saline waters from the marine environment. Nutrients are normally utilized rapidly by the large populations of organisms occurring in the estuary. Normally, spring and late fall plankton blooms occur. Intense zooplankton grazing during the summer contributes to the relatively high productivity commonly found. The upper, less saline portions of many of the estuaries in the Atlantic regions are used as breeding and nursery grounds by commercially important anadromous (fish which swim from the ocean into fresh or nearly fresh water to breed) species. A listing of these organisms appears in the Active Swimmers - Nekton section. Natural stresses in these habitats include large scale variations in temperature and salinities, and high turbidities. Most species normally occurring in this type of community are motile (with the exception of plankton) and can avoid stressful circumstances.

Plankton undergo the same seasonal changes in dominance as was described in the sections on offshore plankton.

Dominant zooplankters include *Acartia tonsa* and *A. clausi* which is the cooler water species. *Eurytemora* spp., *Nemysis americana*, *Oithona*, and *Pseudodiaptomus coronatus* are also important zooplanktonic organisms.

Nine species of diatoms and four species of dinoflagellates comprise the dominant phytoplankers in the Atlantic estuaries. *Skeletonema costatum* is normally dominant with concentrations as high as 35×10^6 cells per liter of water (Bellis, 1974).

Herring, anchovies, smelt, and minnows graze on the plankton and serve as food sources for larger organisms such as weakfish and striped bass.

Man-induced stresses on this habitat type include introduction of untreated sewage, hydrocarbons associated with agriculture (primarily pesticides), high silt levels resulting from dredging activities, oil and its derivatives, and thermal loadings. Sewage effluent adds nutrients to the water, accentuating natural plankton and macrophyte growth levels. This growth utilizes oxygen, eventually causing low dissolved oxygen levels which are stressful if not fatal to most estuarine organisms. Heavy metals have been added to estuaries for a period of years primarily from industrial wastes. These metals are primarily incorporated in sediment, and resuspension of these sediments by dredging may result in localized stresses on susceptible organisms. Long lived pesticides have been deleterious to estuarine waters. DDT, for instance, has been incorporated in sediments in serious quantities (TRIGOM, 1974). The effects of oil on the biota of a northern temperate estuary (Chedabucto Bay) has been described in the section on salt marshes. Thus, the estuaries of the Atlantic coast are presently under varying degrees of man-induced stress.

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c. Resources of the Coastal Zone

(1) Land Use

North and Mid-Atlantic

This discussion of land use for the North Atlantic and Mid-Atlantic areas was derived from the North Atlantic Regional (NAR) Water Resources Study prepared by the North Atlantic Regional Water Resources Study Group for the North Atlantic Regional Water Resources Study Coordinating Committee (U.S. Army Corps of Engineers). The NAR extends from the River Basin in Northern Maine to the James River Basin in Southern Virginia. The region has been divided into 21 hydrologically defined areas, and the following NAR areas have been included in this statement:

NAR	Description
5	Maine Coastal Basin
6	Southern Maine and Coastal New Hampshire
9	Southeastern New England
10	Thames and Housatonic River Basins
13	Southeastern New York Metropolitan Area
14	Northern New Jersey
15	Delaware River Basin
16	Coastal New Jersey
18	Chesapeake Bay and Delmarva Peninsula Drainage
19	Potomac River Basin
20	Rappahannock and York River Basins
21	James River Basin

The University of Rhode Island's (URI) Coastal and Offshore Environmental Inventory--Cape Hatteras to Nantucket Shoals uses the NAR Study for its discussion of coastal zone utilization. Information for areas nine through 21 was obtained from the URI inventory.

Data on shoreline ownership and use were found in the National Shoreline Study--Regional Inventory Report--North Atlantic Region, Vol. 1 prepared by the Department of the Army, Corps of Engineers (1971).

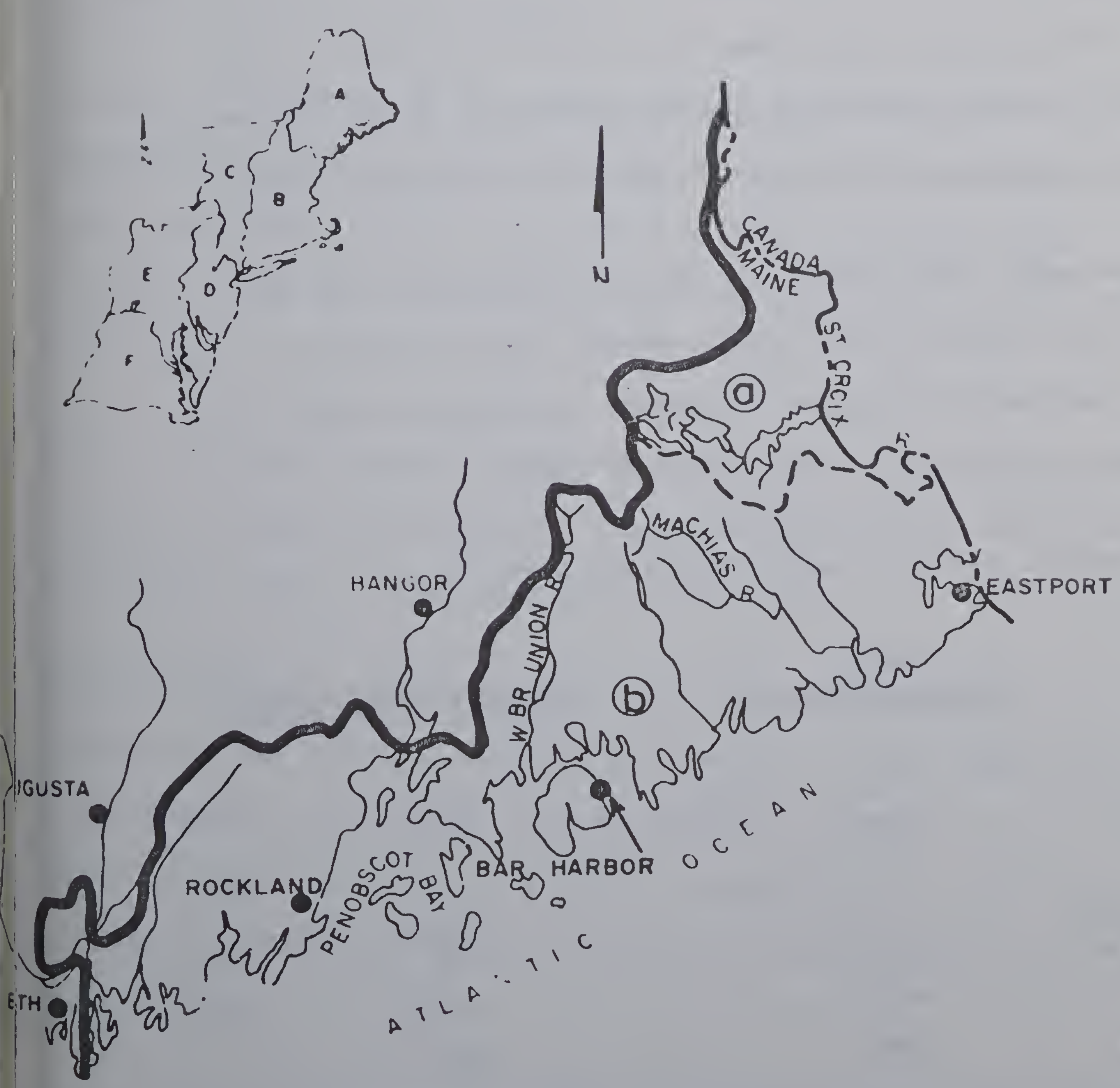
The general land use descriptions for the South Atlantic area are from information provided the Bureau of Land Management by Planners Incorporated, Washington, D.C.

NAR Area 5 - Maine Coastal Basin

This area consists of the coastal portions of Maine from Calais on the north to the mouth of the Androscoggin River on the south. The area is characterized by a rugged, rocky shoreline with many deep narrow inlets and coastal islands.

Of the approximately 1900 miles of exposed shoreline in this area, only 10 miles are beaches. Ownership of this portion of the Maine coastline is divided into 10 miles public (State/local), 10 miles Federal, and the remaining private. There are widely scattered State parks along the Maine shoreline as well as Acadia National Park (30,000 acres). The uses of the shoreline are primarily coastal living and tourism. Of the 1900 miles of shoreline, it is estimated that 5 miles are publicly used, 445 miles are of private recreational use and 1200 miles are undeveloped.

AREA 5 MAINE COASTAL BASINS



There are three major rivers and also a large number of smaller rivers and streams flowing into the coastal and estuarine waters of the area. These streams coupled with the many bays and inlets create a variety of estuarine and wetland regimes, rocky shores and some sandy beach and make this the most naturally diverse area of the entire North Atlantic Region coastal zone.

One of the characteristics which makes this area outstanding is the distinct lack of major urban areas and concentrations of population. It is the least densely populated area within the NAR coastal zone.

A land use and water area summary for Area 5 is shown in Table 29 which lists total land and water area together with the amounts and percent distribution of types of surface coverage (cropland, pasture, forest, urban, water area, other in 1963).

Table 29. Land Use and Water Area, NAR Area 5, 1963

Cover Type	Amount (thousand acres)	Percent Distribution
Cropland	215	6
Pasture	15	minute
Forest	2,974	75
Urban	126	3
Water		
Under 40 acres	8	minute
Over 40 acres	515	13
Other	135	3
Total	3,988	100

Major coastal uses are commercial fishing, recreation including sport fishing, sand and gravel mining, and waste disposal.

NAR Area 6 - Southern Maine and New Hampshire

The coastal portion of Area 6 extends from the mouth of the Androscoggin River in Maine, southwest to the border of New Hampshire and Massachusetts. This area shows a variety of physical characteristics which range from rugged rocky shoreline to sandy beaches and marsh areas.

The section northeast of Portland, principally Casco Bay, has deep rock embayments and is similar to the rockbound shoreline of "down east" Maine. While it does have at least 50 percent rocky outcrops, it is the transition zone from the rocky shore to the sand beach shore.

South of Portland the sandy beach and marsh regime is predominant. There are a number of substantial crescent-shaped beaches which have good quality sand, suitable for beach recreation.

The New Hampshire shoreline is characterized by extensive barrier beaches in front of tidal marshes in the south and rock ledges with pocket beaches in the north. The New Hampshire shoreline includes the shores of Great and Little Bays and the navigable parts of the rivers which flow into the bays (none of which are navigable much beyond eight miles inland).

The coastline of this area is 640 miles long, of which approximately 75 miles are beaches. Ownership of the southern Maine and New Hampshire shoreline is divided into 60 miles public (State/local) and 12 miles Federal, with the remainder under private ownership. The use of the shoreline is primarily recreational. Of the total shorefront, approximately 16 miles are open to public use, 554 miles are used for private recreational purposes, 10 miles are non-recreational, and 60 miles are underdeveloped.

A land use and water area summary for Area 6 is shown in Table 30 which lists total land and water area together with the amounts and percent distribution of types of surface coverage (cropland, pasture, forest, urban, water area, other in 1963).

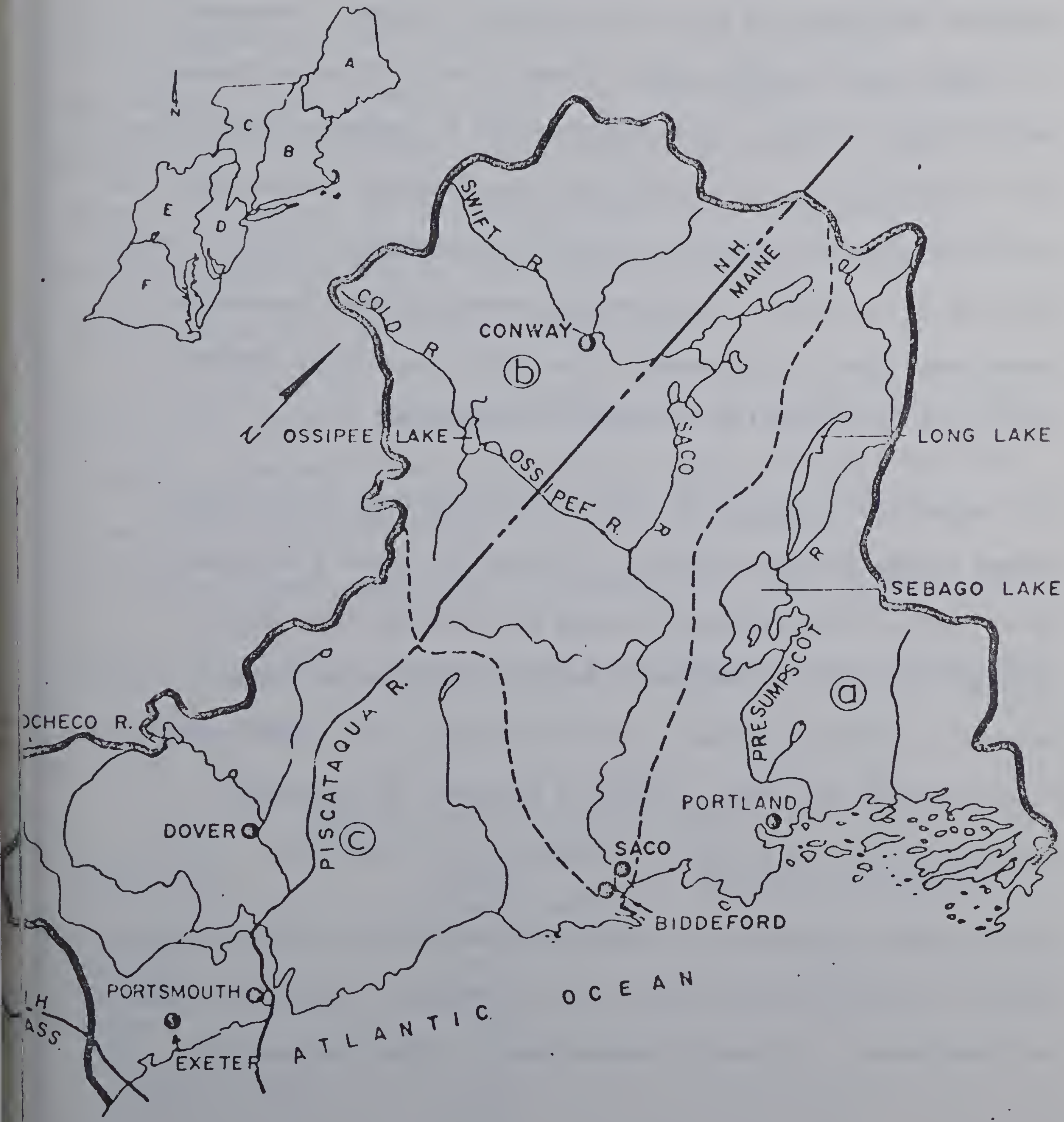
Table 30. Land Use and Water Area 6 - 1963

Cover Type	Amount (thousand acres)	Percent Distribution
Cropland	170	6
Pasture	34	1
Forest	1,970	73
Urban	142	5
Water		
Under 40 acres	15	1
Over 40 acres	206	8
Other	155	6
Total	2,692	100

Major coastal uses are recreation, transportation, sand and gravel mining, and waste disposal.

596

AREA 6 SOUTHERN MAINE AND COASTAL NEW HAMPSHIRE



NAR Area 9 - Southeastern New England

The coastline of Massachusetts north of Cape Cod (Provincetown) measures 460 miles, of which 340 miles are beaches. Ownership is divided into 75 miles public (State/local), 35 miles Federal, and 350 miles private. From Provincetown to Pemberton Point, the major shoreline use is summer recreational/summer residential. In the Boston Complex (Pemberton Point thru Beverly), the major shoreline use is associated with heavily industrialized, commercial waterfront type of development. The major use of the remaining portion of the shoreline is summer recreational.

The Massachusetts shoreline south of Provincetown to the Rhode Island border covers 440 miles, of which 370 miles are beaches. Sandy beach areas predominate along the southern Cape while coastal areas west of Buzzard's Bay show more variety with a mixture of barrier beaches, deep indentations, low rocky headlands, marshes and ponds. Martha's Vineyard and Nantucket dominate a group of offshore islands south of the Cape.

The southern Massachusetts coastline is nearly 78% privately-owned, 11% public (State/local) and 11% Federal. Shoreline use in these areas is primarily recreational. Major recreational sites include municipal beaches, State parks (3) and the federally-owned Monomoy Wildlife Reserve and Cape Cod National Seashore.

The 340 mile-long Rhode Island shoreline consists of a southerly sector (190 miles) which includes Block Island and fronts essentially on the Atlantic Ocean, and a Narragansett Bay sector (150 miles). The southern sector contains 140 miles of beach front and is nearly 74% privately-owned; state/local ownership amounts to 21% and Federal, less than 3%. Narragansett Bay shorefront is more than 90% privately-owned.

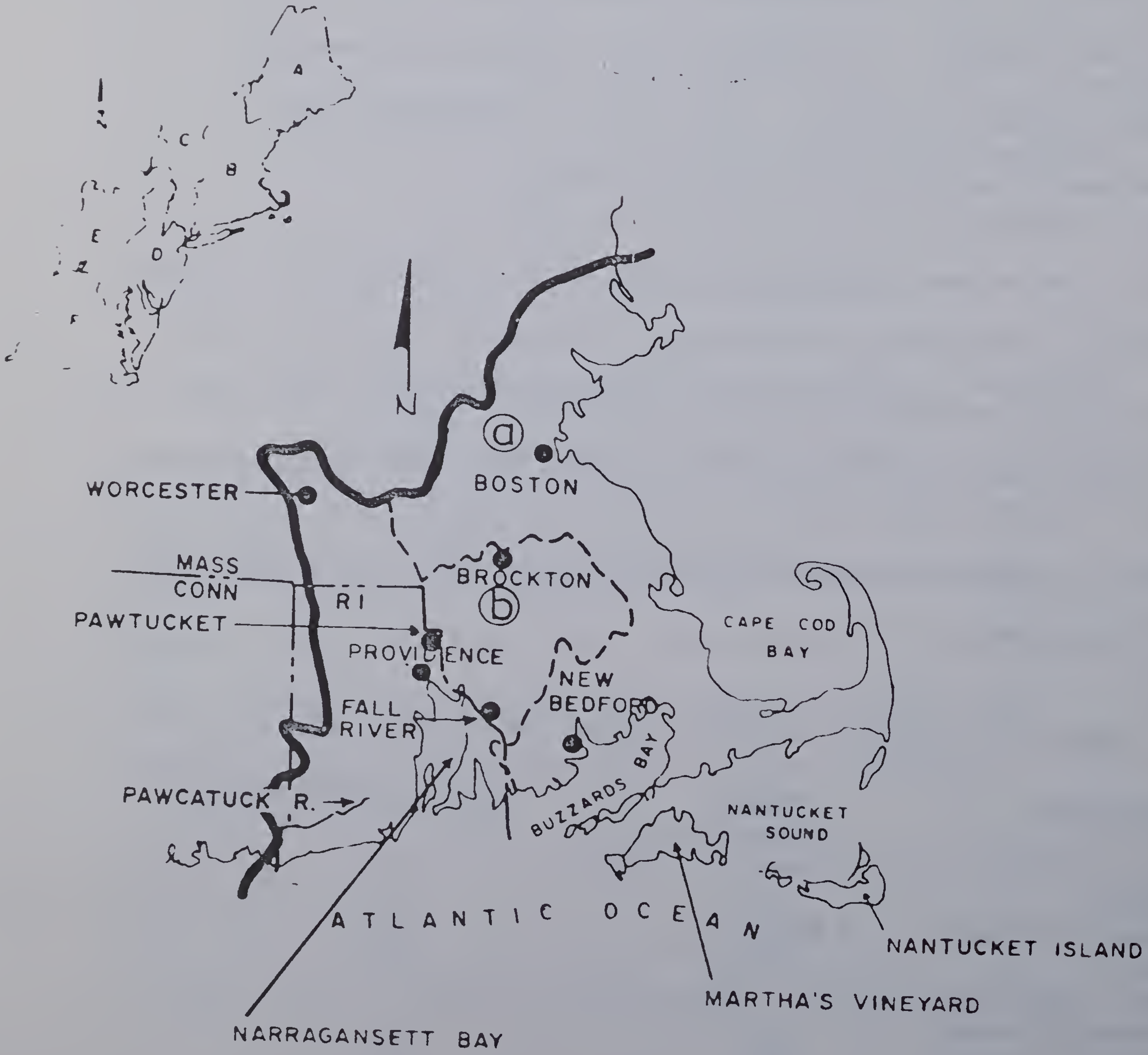
Most of the southern New England shore area is used for recreational purposes. Commercial and industrial uses occur locally near urban areas within Narragansett Bay (Providence and Newport, R.I. and Fall River, Mass.) and along the southern coast (New Bedford, Mass.).

Table 31 presents a summary of land use and water areas within NAR Area 9, for 1963.

Table 31. Land-Use and Water Area, NAR Area 9 - 1963

Cover Type	Amount (thousand acres)	Percent Distribution
Cropland	145	5
Pasture	59	2
Forest	6,616	55
Urban	518	18
Water		
- under 40 acres	28	1
- over 40 acres	282	10
Other	280	9
TOTAL	2,928	100

AREA 9 SOUTHEASTERN NEW ENGLAND



NAR Area 10 - Connecticut

Connecticut has an irregular coastline with many bays, coves, and promontories. Several small offshore islands dot its central and western portions. Of the approximately 270 miles of shoreline, some 145 miles are beaches located primarily east of Norwalk Harbor. Many of these are narrow, and normal tides approaching the backshore make them inadequate as protective features or as recreational areas without some modification. West of Norwalk Harbor, the coastline is rockier.

Ownership of the Connecticut shores is divided as follows: 50 miles State/local, 5 miles Federal, and 215 miles private. The publicly-owned property includes four State parks and associated beaches, numerous scattered town and city beaches, and two Coast Guard facilities. The use of the shorefront is primarily summer and permanent residential, public recreational, and commercial-industrial within the urban areas. Thirty miles of the shore are devoted to public recreational use. There are 225 miles devoted to private recreation, and the remainder to non-recreational private development. Public beaches attract numerous visitors from surrounding areas, with 10 million annual visits having been recorded for 18 cooperative beach projects within the area. Residential development consists generally of private associations and privately-owned homes, both seasonal and year-round.

A land-use and water area summary for Area 10 (Thames and Housatonic River Basins) is shown in Table 32 which lists total surface areas together with the amounts and percent distribution of types of surface coverage in 1963.

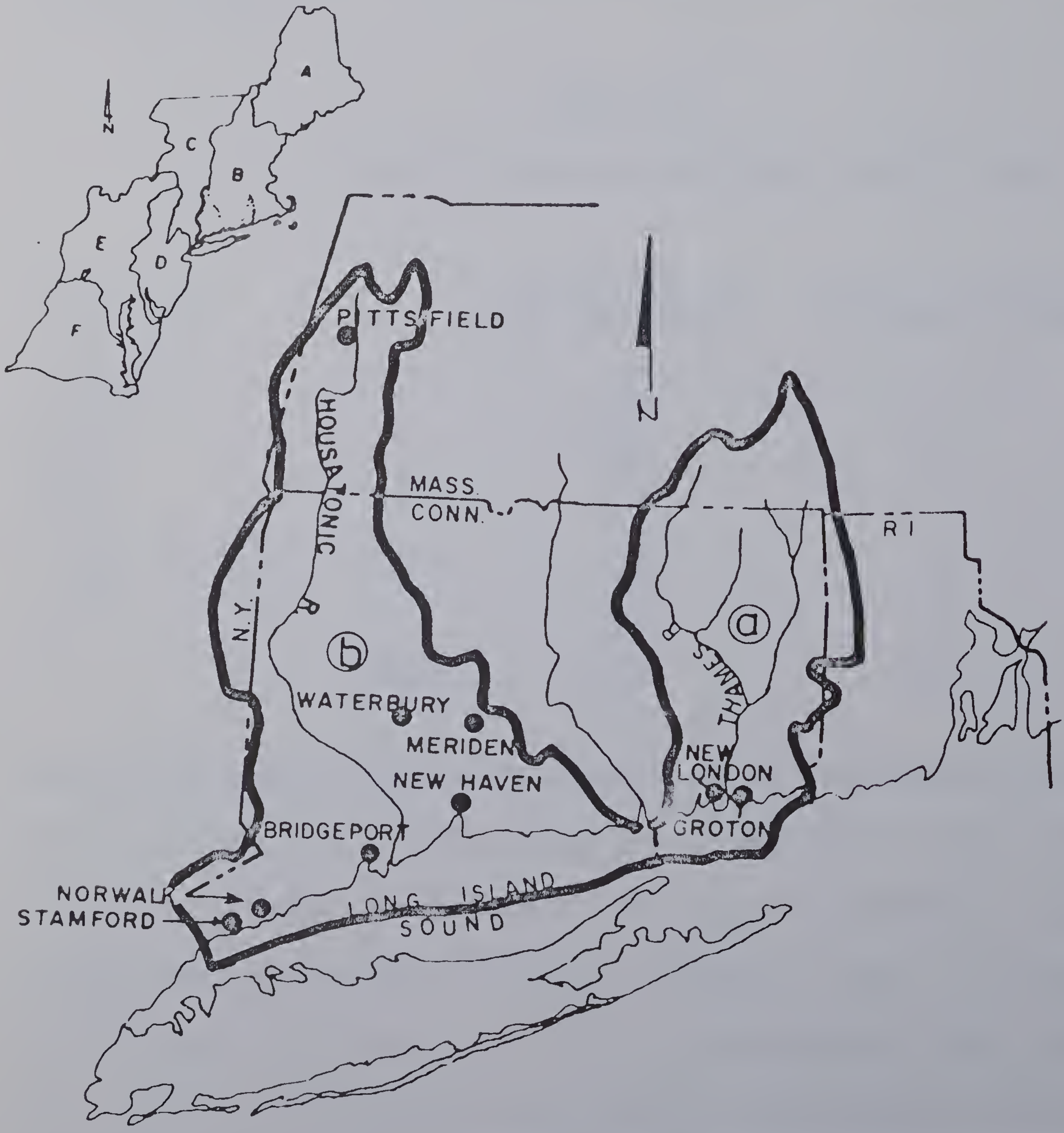
Table 32.

LAND-USE AND WATER AREA NAR AREA 10 - 1963

Cover Type	Amount (Thousand Acres)	Percent Distribution
Cropland	237	8
Pasture	159	5
Forest	1,922	66
Urban	249	9
Water		
over 40 acres	76	3
under 40 acres	28	1
Other	245	8
Total	2,916	100

Despite the heavy population concentration in the western coastal section of Area 10, a large proportion of the land is still considered open space. These areas, however, are predominantly in private ownership as part of large residential tracts. Only two State parks are located in this area, Sherwood Island State Park and Silver Sands State Park, and little of the available beach area is open to the public. Commercial and industrial land-use predominates in Norwalk, Bridgeport, and New Haven. From New Haven east, almost all the land is classified as residential and open space. An exception is the New London area where a significant portion of the land is Federally-owned or zoned for industrial use. Three State parks are located on this portion of the coast--Hammonassett, Rocky Neck, and Harkness Memorial.

AREA 10 THAMES AND HOUSATONIC RIVER BASINS



NAR Area 13 - Southeastern New York - Metropolitan

Area 13 contains the coastal areas of Long Island (Nassau and Suffolk counties) and the coastal reaches of the Hudson estuary (New York City and Westchester county). The Nassau-Suffolk area is a 1,200-square mile, 20 mile wide peninsula extending 100 miles to the east. It has an exposed Atlantic-oriented flank on the south and a semi-protected Sound-oriented flank on the north. Its total coastline is over 500 miles long. The Westchester coast and the western half of the Long Island coast are very irregular, with numerous deep bays and promontories. Eastward the coast becomes regular with ver few indentations. Along the entire North Shore, beaches are generally narrow and rocky or pebbly, and usually front high bluffs or small marshes. Except at the heads of embayments, large wetlands are uncommon. Along the Sound, beaches make up 8 of the 42 miles of the coast in Westchester County, 5 of 18 in Nassau County and 75 of 87 in Suffolk County.

The East Shore, with 168 miles of shoreline between Orient and Montauk Points, is almost all beaches, many of which are gravelly and very narrow. They front low bluffs on the north fork and glacial headlands up to 240 feet high on the south fork. Wetlands are common, particularly along the westernmost part of this shoreline. The 108 mile South Shore consists of long, wide, sandy barrier beaches facing a strong Atlantic surf. Behind these barrier beaches, for almost the entire South Shore, are long, narrow, quiet backbays.

The Hudson estuary comprises a few narrow strips of sand, marsh and railroad tracks behind which the land rises sharply and falls away inland into rolling forested highlands. Farther south, the steep cliffs of the Palisades across from upper Manhattan mark a transition into the busy urban atmosphere of New York Harbor. Much of the 290-mile shorefront is lined with piers, wharfs, and docks along the Harbor's bays and rivers. Behind the waterfront, urban structures dominate the view, and there are numerous bridges, tunnels and airports. Seaward of the Verranzano Bridge, which marks the harbor entrance, the 28 miles of oceanfront is all beach. A net westward movement of sand along the barrier beaches of southern Long Island necessitates repeated dredging to maintain channels to New York Harbor.

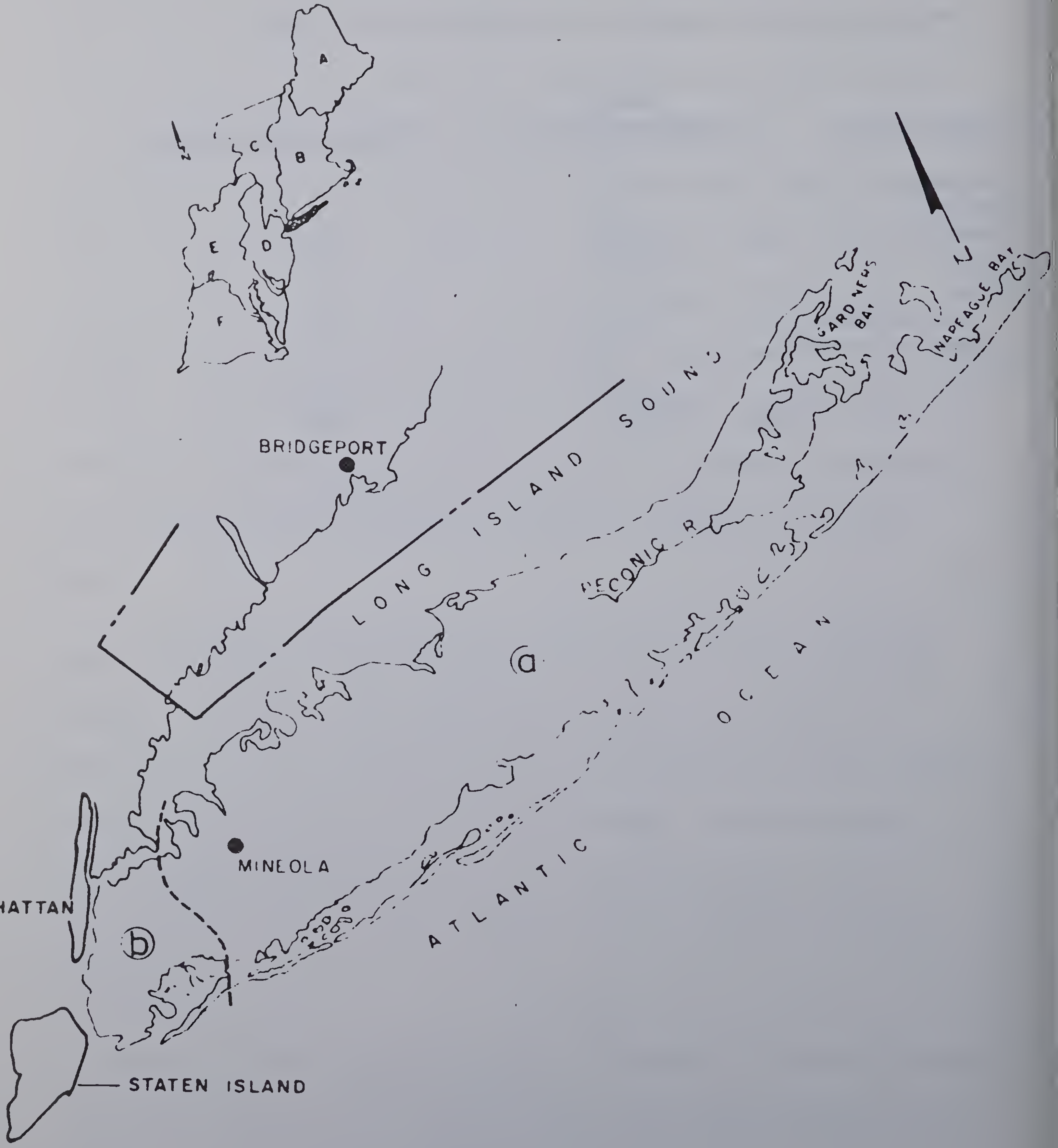
Annual attendance at beaches in New York City in recent years has exceeded 30 million, even though water quality for swimming has been marginal. Staten Island beaches draw about one million people annually, Coney Island about 10 million people and the Rockaway beaches about 20 million people. The long oceanfront beaches are especially ideal for most forms of beach and water-contact recreation.

A land-use and water summary for Area 13 is shown in Table 33 which lists total surface areas together with amounts and percent contribution of types of surface coverage in 1963.

Table 33. Land Use and Water Area NAR Area 13 - 1963

Cover Type	Amount (thousand acres)	Percent Distribution
Cropland	63	5
Pasture	4	--
Forest	361	30
Urban	548	45
Water		
Over 40 acres	163	13
Under 40 acres	1	--
Other	77	7
TOTAL	1,217	100

AREA 13 SOUTHEASTERN NEW YORK METROPOLITAN R



Subregion C. Area 14 - Northern New Jersey

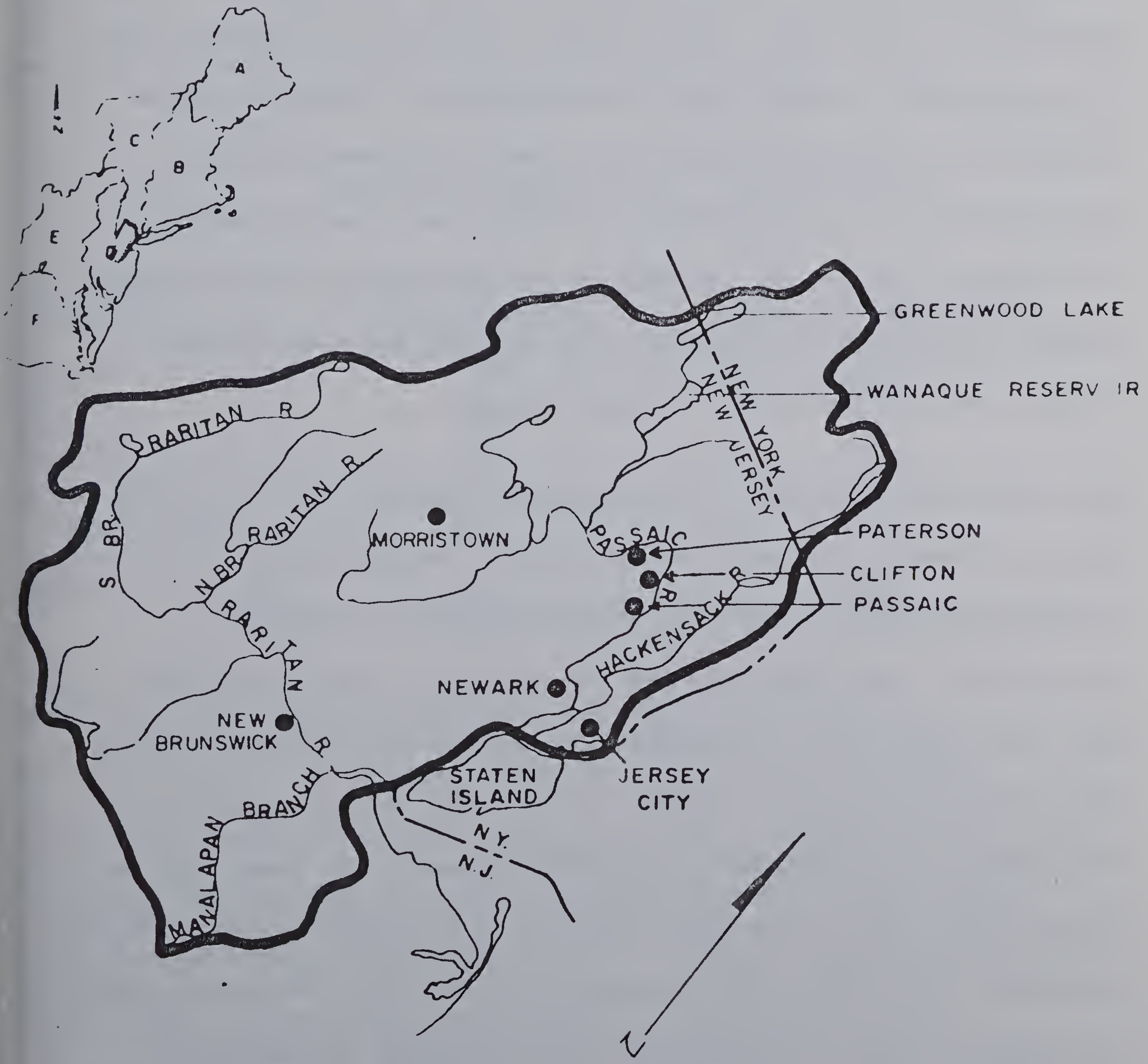
This area includes the basins of northeastern New Jersey beginning with the shore of the Hudson River and including the Hackensack, Passaic and Raritan basins, Newark Bay and the New Jersey portions of the channel around Staten Island--Arthur Kill and Kill Van Kull. The area is characterized by low flat topography and extensive tidal marshes, many of which have been reclaimed with landfill. The cliffs of the Palisades along the Hudson comprise the major natural topographic feature in the coastal zone. Nearly two-thirds (1500 sq. miles) of Area 14 consists of rolling hills with the balance (800 sq. miles) in undulating land. Over 52 percent of the area consists of city landscape units (1200 sq. miles), and intensive urban development--piers, skyscrapers, bridges--is the predominant characteristic of the coastal reaches. Table 34 gives land use and water coverage for NAR Area 14, in 1963.

Table 34. Land-Use and Water Area - Area 14 - 1963

Cover Type	Amount (Thousand Acres)	Percent Distribution
Cropland	229	15
Pasture	45	3
Forest	588	39
Urban	448	29
Water		
over 40 acres	40	--
under 40 acres	8	3
Other	162	11
Total	1,520	100

Commercial navigation is one of the most important activities in Area 14, and the amount of waterborne commerce is one of the highest of the entire North Atlantic Region. Commercial navigation directly supports industries which are major water users, including several power companies.

AREA 14 NORTHERN NEW JERSEY



NAR Area 16 - Coastal New Jersey

The coastal zone of New Jersey includes the shore of Raritan Bay between the Raritan River and Sandy Hook, and the ocean shore from Sandy Hook to Cape May. The 20 miles of shorefront on Raritan Bay is characterized by high bluffs and marshlands fronted by narrow beaches and intersected by numerous creeks influenced by tides. The 125 miles of ocean shorefront in this area consists entirely of beaches. Most of the beaches are on long, sandy barrier islands. Behind the beaches are backbays, salt marshes and meadows that extend several miles inland in some places.

Ownership of the 20 miles of shorefront on Raritan Bay is divided into 13 miles private and 7 miles public. In this reach, shore development is primarily residential and recreational in character, with some commerce and industry. South of Raritan Bay, from Sandy Hook to Cape May, the pattern of oceanfront ownership is 80 miles public, 30 miles private and 15 miles Federal. The shores of the backbays are largely wetlands, but there are more beaches there than along other backbays in the North Atlantic Region. Shoreline ownership along the backbays is largely private, and shore development is again recreational and residential in character.

Table 35 lists total surface areas together with the amounts and percent distribution of types of surface coverage in 1963.

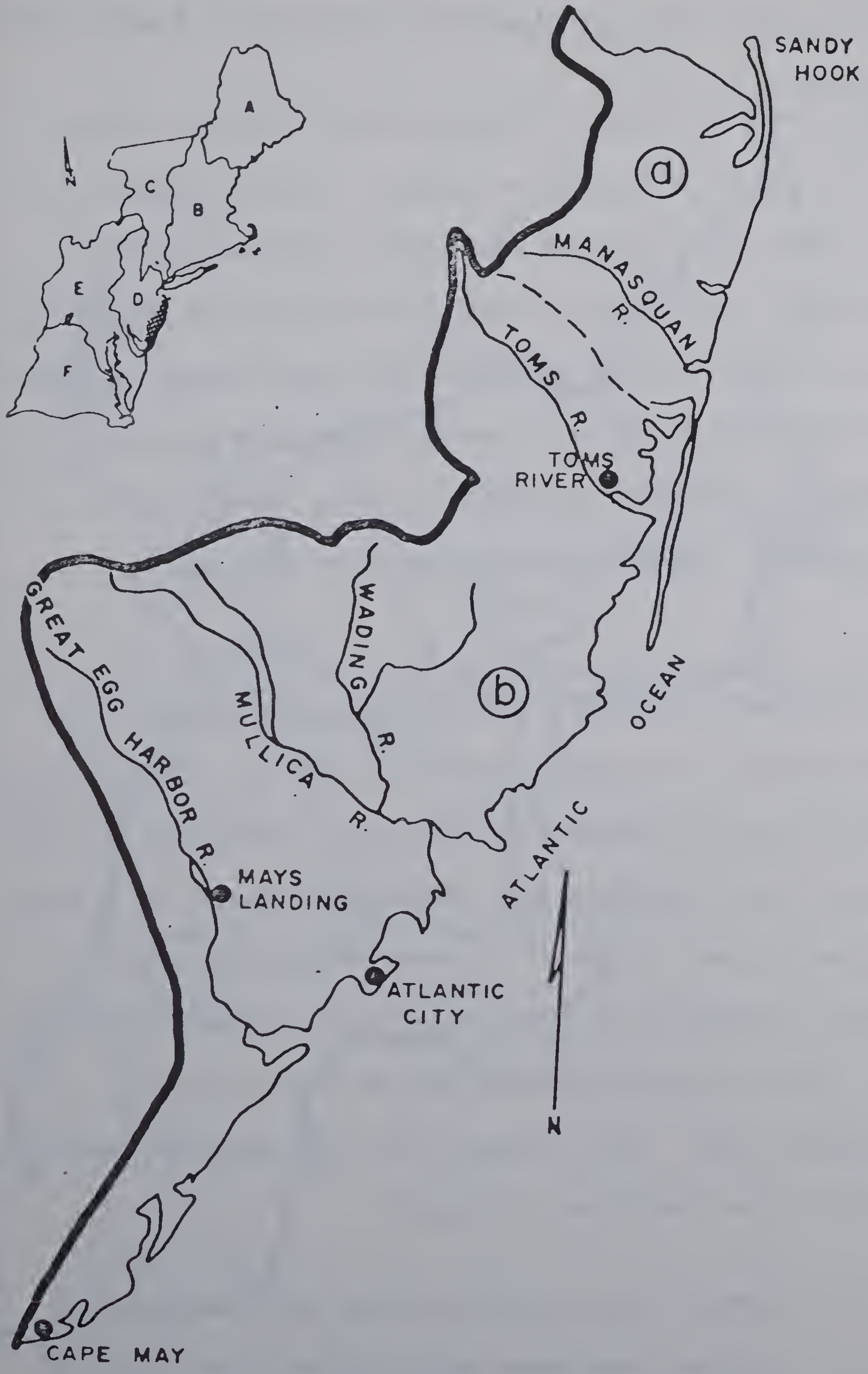
Table 35. Land-Use and Water Area - Area 16 - 1963

Cover Type	Amount (thousand acres)	Percent Distribution
Cropland	212	14
Pasture	21	1
Forest	760	50
Urban	204	13
Water		
over 40 acres	121	8
under 40 acres	2	--
Other	212	14
Total	1,532	100

Land use in the Area 16 coastal zone is mostly residential and recreational. The barrier beach is so heavily developed that virtually no vacant beachfront exists, with the exceptions of State-and Federally-owned beaches and scattered vacant parcels around inlets. Commercial land use is concentrated in the central business districts of the larger resort towns, and adjacent to the boardwalks and promenades. Industrial land use is minimal throughout the shore area, most of it occurring along Raritan Bay. Some Federally controlled lands no longer of military value such as Fort Hancock on Sandy Hook are being phased out. New Jersey leases part of Sandy Hook beachfront to accommodate intensive day-use recreational demand. The marshlands and portions of mainland facing the barrier beaches have only recently begun to be developed as lagoons providing marinas, homes and boating facilities. Large portions of the coastal marshlands have already been reserved as State and Federal wildlife refuges.

Recreational boating is the most significant aspect of navigation in Area 16. Area 16 helps satisfy the recreational needs of Areas 14 and 15, as well as serving many transient boats from both within and outside the NAR.

AREA 16 COASTAL NEW JERSEY



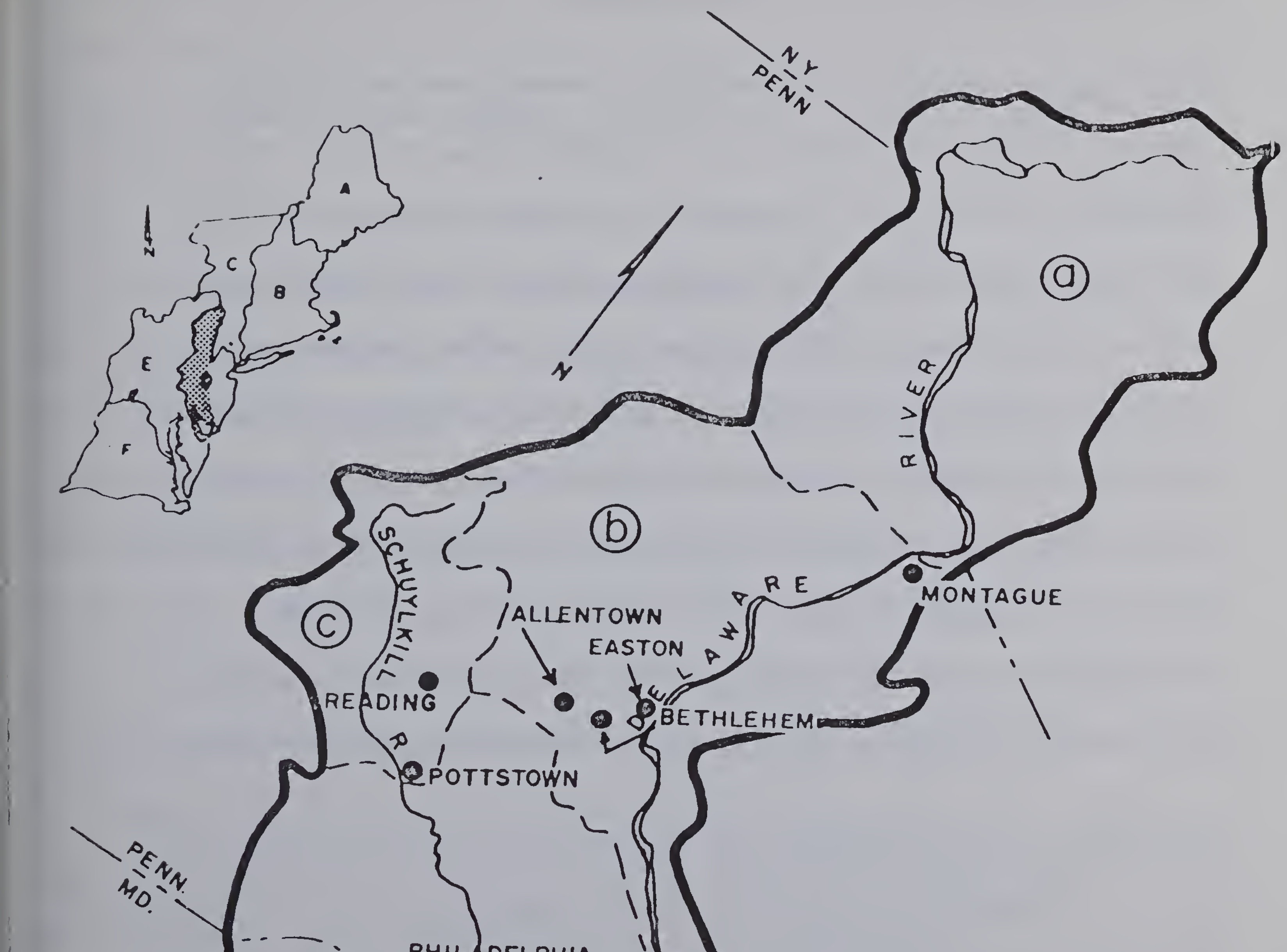
Area 15 - Delaware River Basin (Philadelphia and Coastal Reaches Only).

The coastline of Area 15 consists of Delaware Bay and the Delaware River to the head of the tidewater in Trenton. From Philadephia south to Penns Grove, the waterfront is highly developed on both banks for industrial and commercial use. The 85 miles of shoreline from Penns Grove to Cape May on the New Jersey side consist of about 50 miles of wetlands and 35 miles of narrow sand beach fronting marshes. Ownership is apportioned about 45 miles private, 20 Federal and 20 public. Twelve miles of the shore line are residential.

The 82 miles of Delaware shoreline from Wilmington to Cape Henlopen consist almost entirely of marshes in the north and of a narrow strip of sand beach fronting more marshes in the south. Ownership is about 57 miles private, 14 public and 11 Federal. Except for 9 miles for public recreation and 2 miles for commercial purposes, the entire shoreline is undeveloped. Shoreline use is primarily wetland conservation. Little bathing occurs in the bay and shoreline fishing is generally poor. Bay fishing by boat has improved in recent years and is now considered to be good.

Major uses of the Delaware Basin area are marine and land transportation, crude oil refining, waterborne waste disposal, municipal water supply, and wetlands conservation.

AREA 15 DELAWARE RIVER BASIN



NAR Areas 18-21 - Chesapeake Bay Region

This region comprises the Chesapeake Estuary and the Atlantic coastal portions of Delaware and Maryland (Area 18 - See Fig together with the major sub-estuarine system draining into the Bay--the Potomac River, the Rappahannock and York River Basins, and the James River. The Chesapeake Bay is the largest estuary on the Atlantic coast, receiving water from a drainage basin of 65,476 square miles. The Bay is about 200 miles long; its width varies from 4 to 35 miles of shoreline, two-thirds of which is in the State of Maryland. The Bay's largest tributary is the Susquehanna, the largest river on the Atlantic coast, and the Potomac River provides the largest of the Bay's many sub-estuari .

The shore of the Chesapeake Bay may be characterized in general as a zone of submergence, with its typical submerged river channels, loose sedimentary deposits, wetlands, and erodable bluffs.

Of approximately 1,900 miles of non-ocean Maryland shoreline, about 280 are on the Bay proper and the rest are on the tributaries. The Maryland shoreline consists almost entirely of extensive wetlands on the eastern shore and banks, with bluffs and wetlands on the western shore. Less than 1% (15 miles) of the shore can be considered beach. Ownership is divided about 1670 miles private, 200 Federal and 30 public. Most of the Federal ownership is concentrated in wildlife areas on the eastern shore and in several military installations on the western shore which include Aberdeen Proving Grounds, Edgewood Arsenal, and a number of Navy installations.

The Virginia shoreline on the bay is approximately 900 miles long and, except for some beach development near Hampton Roads and on the southernmost 25 miles of the Delmarva Peninsula, includes only a very few, small scattered beaches. Most of the remaining shoreline is marshy. Many of the marshes, especially on the peninsula, are brackish. Ownership is divided about 735 miles private, 100 public and 65 Federal. Most of the Federal property is concentrated in military installations in the vicinity of Hampton Roads. Of the 900 miles, only 40 are for public recreational use. Except for the commercial and military facilities in the ports, essentially all the remainder is undeveloped marshes, banks, and bluffs.

The ocean sector of the Chesapeake Bay region includes the Atlantic coastal areas of the States of Delaware, Maryland and Virginia. About 120 miles of the ocean front is on the Delmarva Peninsula and 25 miles extend from Cape Henry south to the North Carolina line. All of the ocean front is beach. In Delaware and Maryland it takes the form of long, low, narrow barrier beaches fronting a series of embayments with infrequent narrow inlets connecting them to the ocean. The Virginia shoreline is less uniform. It varies north to south from barrier island, mainland, small buffer islands, mainland and barrier beach. The major embayments are Rehoboth Bay in Delaware, Assawoman Bay in Delaware and Maryland, Sinepuxent Bay in Maryland, Chincoteague Bay in Maryland and Virginia, Hog Island Bay in Virginia and North Carolina. Ocean front ownership is divided about as follows: 45 miles (mostly in the southern part of the Delmarva Peninsula) is private; 65 miles (mostly on Assateague National Seashore and Wallops Island) is Federal; and 35 miles (mostly in Delaware and southern Virginia) is public. About half the beach is used for public recreation. Most of the remaining half is undeveloped. The backbays throughout this sector exhibit the characteristic pattern found almost everywhere throughout the NAR: their shorelines are almost all wetlands and have very little beach area, ownership is almost all private and the principal use is recreational, featuring small boating, sport fishing and wetlands appreciation. Many of the backbays in this sector are brackish.

Land-use and water area summaries for Areas 18 and 20 are shown in Table 36 which lists total surface areas together with the amounts and percent distribution of types of surface coverage in 1963.

le 36. Land-Use and Water Area - Area 18 and 20 - 1963

er Type	Amounts (thousand acres)		Percent Distribution	
	Area 18	Area 20	Area 18	Area 20
rpland	1,766	582	34	15
ature	209	359	4	10
est	1,740	2,441	33	64
ran	228	116	4	3
ater				
ver 40 acres	534	94	10	2
nder 40 acres	29	10	1	--
ter	707	238	6	3
Total	5,213	3,840	100	100

h Carolina Coast - Cape Hatteras to Virginia

Hatteras, North Carolina, defines the southern limit of the le Atlantic Bight. The Cape Hatteras area extends to the inia State line for the purposes of this study. Most of North lina's vast estuarine complex is included in this section ell as much of North Carolina's present and planned development.

coastal zone extending from the North Carolina state line south ape Hatteras consists of a series of habitats which have not been severely influenced by man. This coastal zone complex udes large shallow estuaries, barrier beaches and islands, s, marshes, mudflats and open coastal water.

The Pamlico-Albemarle-Currituck Sound areas of the North Carolina coast are separated from the Atlantic Ocean by a barrier island system known as the Outer Banks.

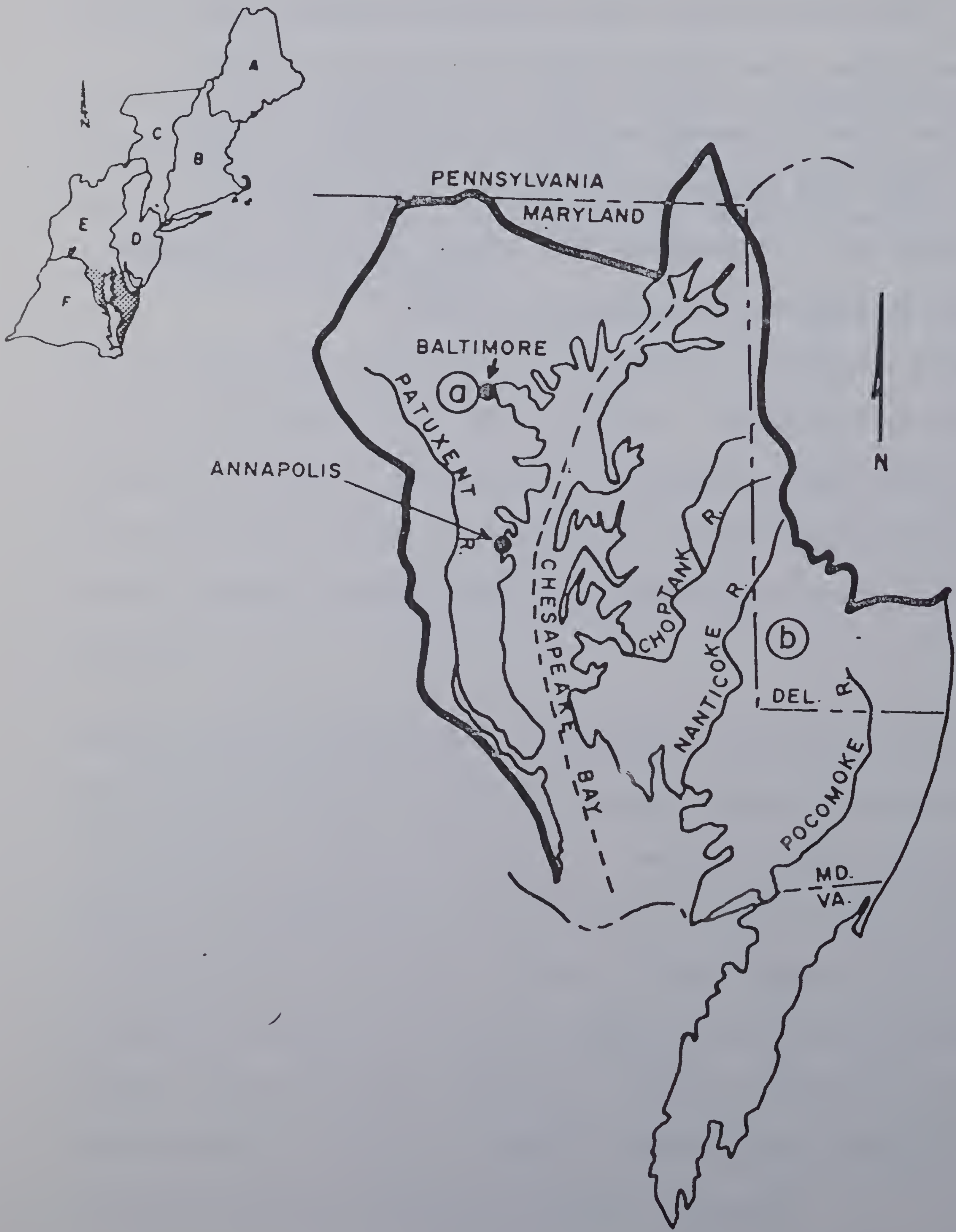
The ocean shoreline areas from Cape Hatteras northward are characterized by a relatively narrow barrier beach with wide sandy beaches backed by dunes. This region also contains several scenic areas and historic landmarks.

In the past, this region has been a producer of tobacco, peanuts, cotton and soybeans, and forest products. Finfish and shellfish resources are also widely utilized. Although a significant amount of agricultural activity continues, it has been supplemented by recent national defense activities, recreational activity and tourism.

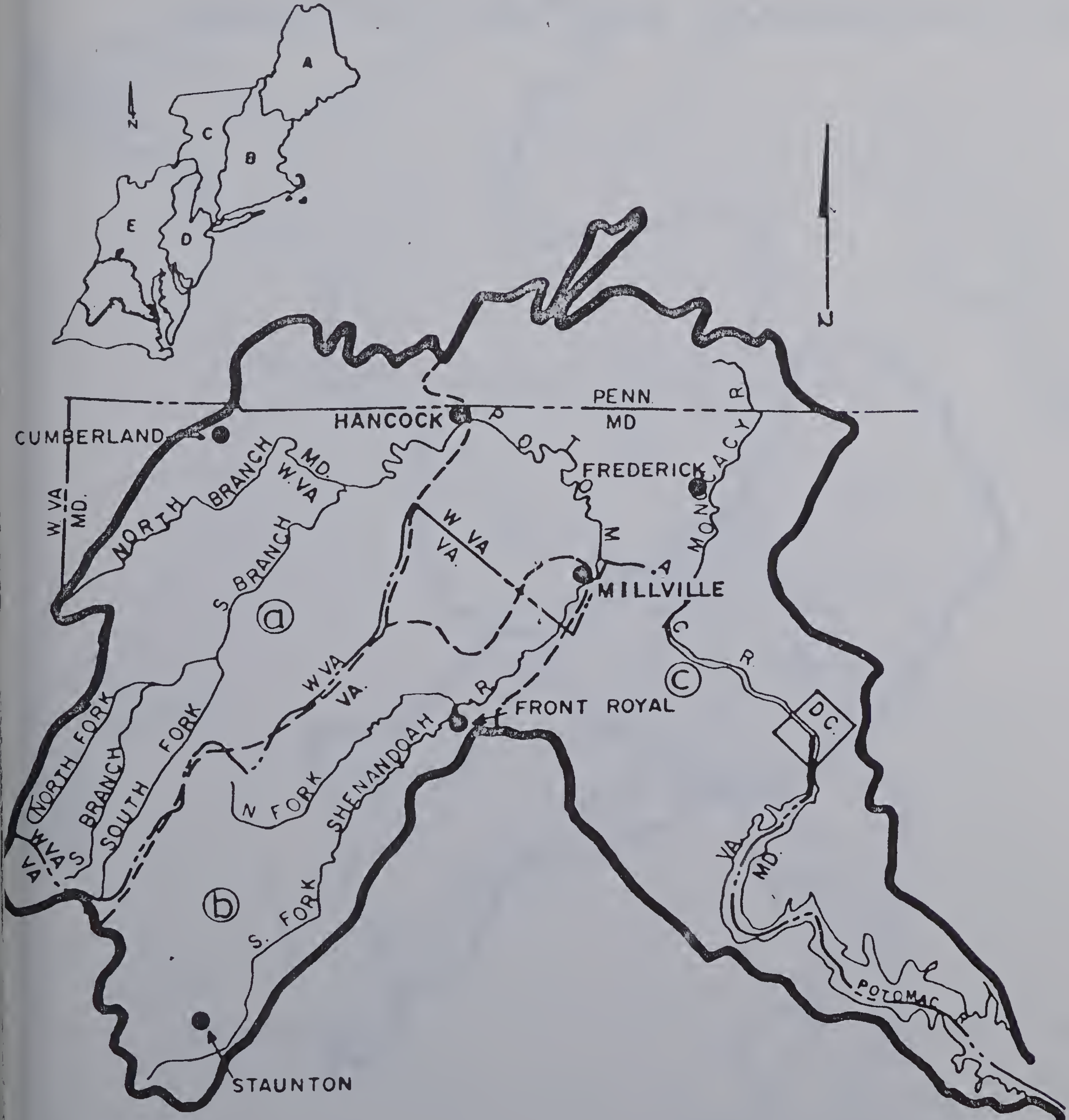
Despite proposed development, a substantial proportion of the approximately 200 mile length of the Outer Banks of North Carolina is classified as national seashore. The Cape Hatteras National Seashore, located south of Cape Hatteras, continues south for another 55 miles. The Cape Hatteras National Seashore has been developed extensively for public recreation and already accomodates nearly 2 million visitors annually. The area between Kitty Hawk and Nags Head, a popular and rapidly expanding recreational area, is being developed primarily by private interests.

A major recreational attraction of the Outer Banks area is the fishing. The commercial fishery is also important and is highly dependent upon the continued health of the estuaries. Two major problems of the North Carolina coastal zone are sand dune and wetland destruction. The State of North Carolina has acted to protect these areas by passing appropriate legislation. Among these are a Sand Dune Protection Act and two acts prohibiting wetland destruction. A dredge and fill law and the Coastal Wetlands Act regulate activity in marshlands and wetlands.

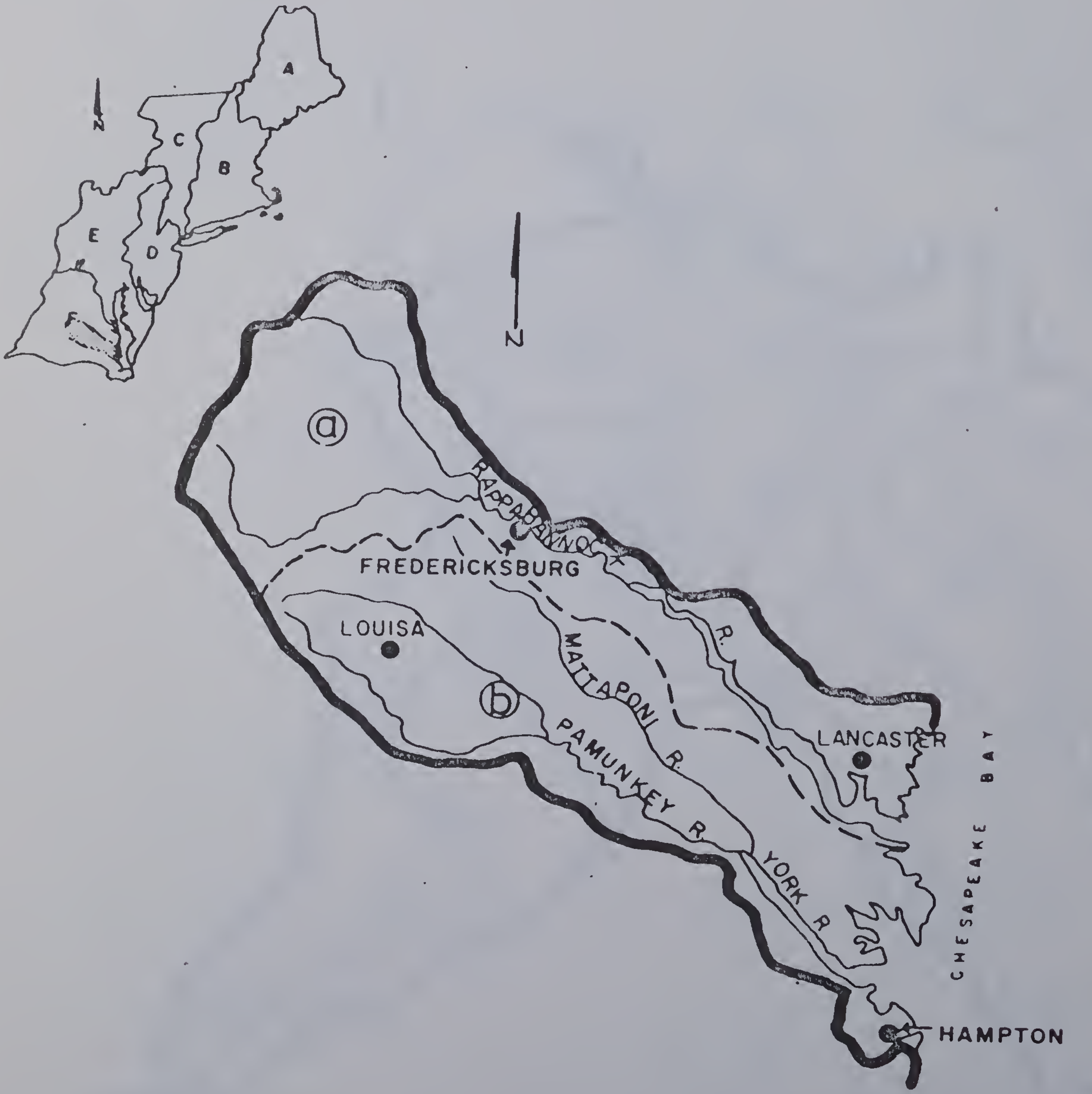
AREA 18 CHESAPEAKE BAY AND DELMARVA PENINSULA DRAINAGE



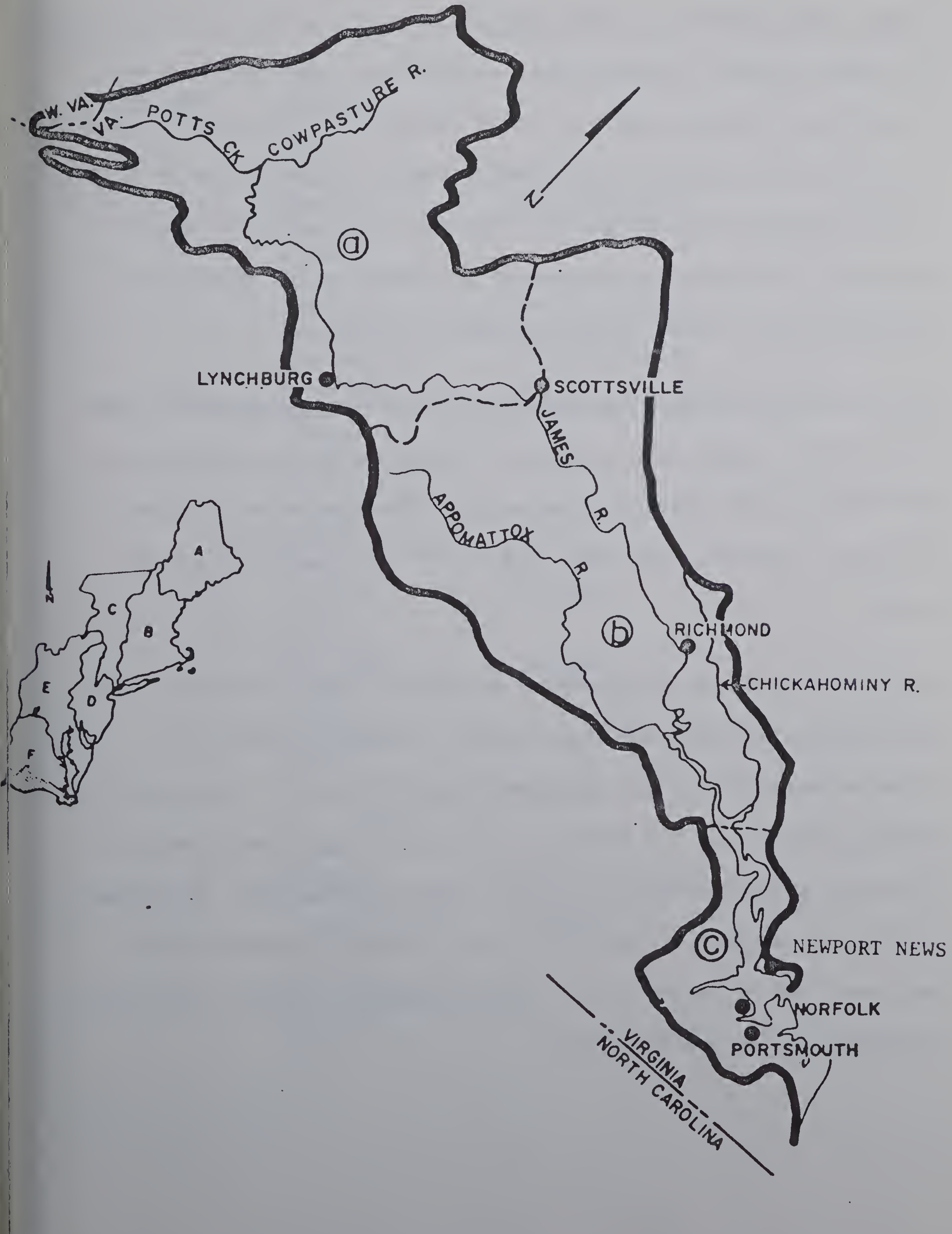
AREA 19 POTOMAC RIVER BASIN



AREA 20 RAPPAHANNOCK AND YORK RIVER BASINS



AREA 21 JAMES RIVER BASIN



South Atlantic

Land Use

General Description of Coastal Area

The South Atlantic coastal region as discussed here is the area between Cape Hatteras and the tip of Florida. These coastal areas are part of the Coastal Plains Region, which begins at the fall line in the Carolinas and Georgia 500 feet above sea level and slopes gently to the Atlantic Ocean nearly 150 miles to the southeast between southern Virginia and northern Florida.

The region has abundant and varied water resources, including nine major rivers, many smaller surface streams, lakes and ponds, vast marshlands and forests, salt water estuaries, protected bays and waterways, harbors, the ocean, and a plentiful supply of ground water.

Numerous environmental management areas are located along the coast. They include national and state parks, national seashores and forests, wildlife refuges and game management areas. These areas place approximately 1.4 million acres of land under environmental controls, excluding much of it from future development. The prime natural attractions of the coast are its miles of sandy beaches, waterways and estuaries which attract swimmers, boaters, and sports fishermen in the summer months.

The land use inventory is presented in terms of coastal counties (see Fig. 109). Counties which form geographical entities are combined into sectors as listed below.

Sector	Counties	
1	Dare	
	Hyde	
	Beaufort	North Carolina
	Pamlico	
	Craven	
	Carteret	
2	Onslow	North Carolina
	Pender	
3	New Hanover	North Carolina
	Brunswick	
4	Horry	South Carolina
	Georgetown	
5	Berkley	South Carolina
	Charleston	
6	Colleton	South Carolina
	Beaufort	
	Jasper	
7	Chatham	Georgia
	Bryan	
8	Liberty	
	McIntosh	Georgia
	Glynn	
	Camden	
	Charlton	
	Nassau	
9	Duval	Florida
	St. Johns	
10	Flagler	
	Volusia	Florida
	Brevard	
11	Indian River	Florida
	St. Lucie	
	Martin	
	Palm Beach	
	Broward	
	Dade	

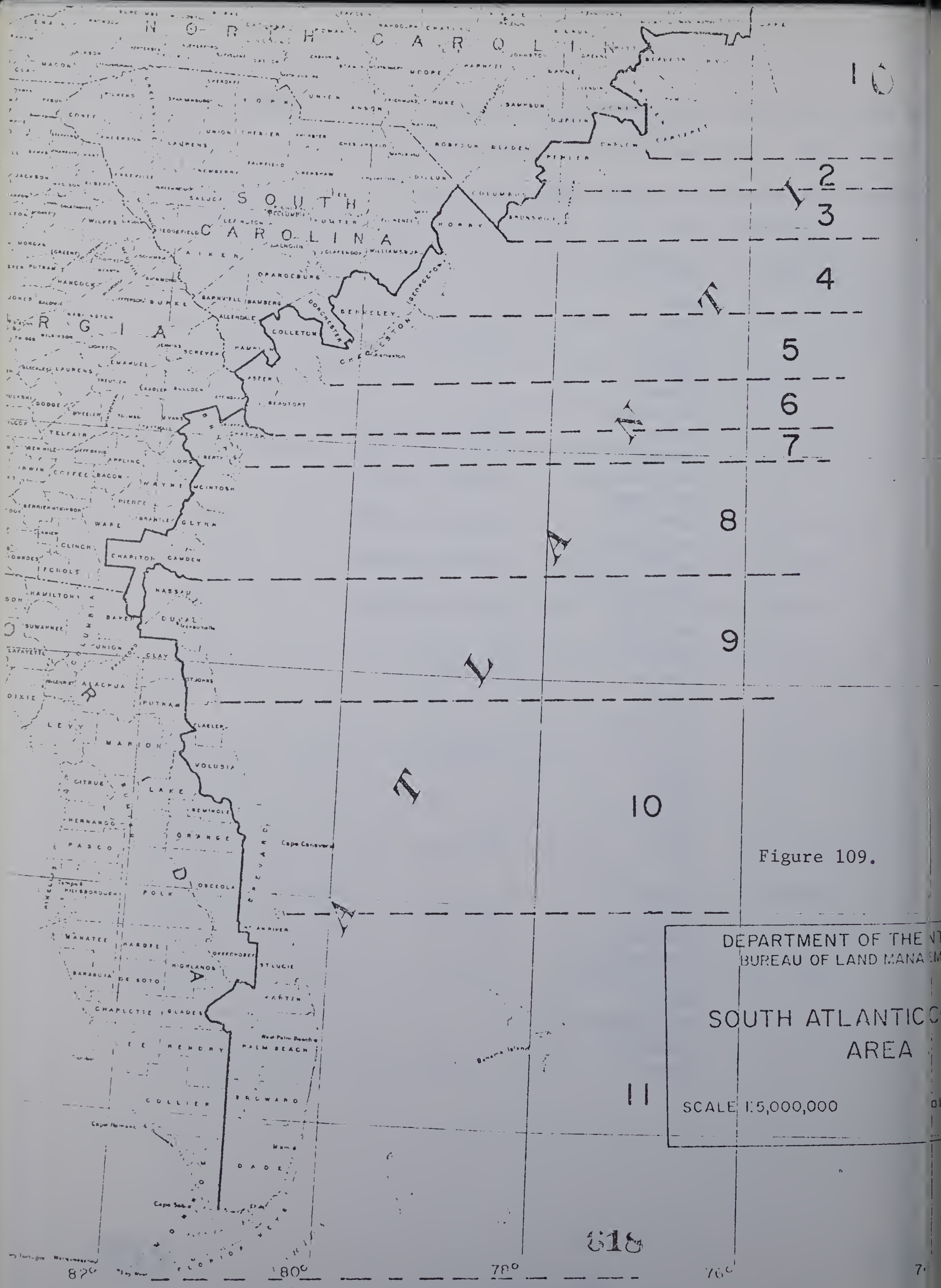

NORTH CAROLINA
SOUTH CAROLINA
GEORGIA
FLORIDA
ATLANTIC
1
2
3
4
5
6
7
8
9
10
11
DEPARTMENT OF THE
BUREAU OF LAND MANA
SOUTH ATLANTIC
AREA
SCALE 1:5,000,000
82°
80°
78°
76°
MACON
PICKENS
OCONEE
ANDERSON
LAURENS
SPARTANBURG
YORK
UNION
CHESTER
ANSON
MOORE
HARNETT
WAYNE
SAMPSON
DUPLIN
ONSLOW
CARTERET
ROBESON
BLADEN
COLUMBUS
BRUNSWICK
PENDER
HORRY
NEWBERRY
FAIRFIELD
KERSHAW
SALUDA
SUMTER
AIKEN
ORANGEBURG
BERKELEY
DORCHESTER
GEORGETOWN
CHARLESTON
COLLETON
HAMPTON
JASPER
BEAUFORT
ALLENDALE
BAMBERG
BARNWELL
BURKE
SCREVEN
BULLOCH
EMANUEL
LAURENS
HANCOCK
CHATHAM
LIBERTY
LONG
MCINTOSH
WAYNE
GLYNN
CAMDEN
CHARLTON
PIERCE
WARE
CLINCH
ECHOLS
BRANTLEY
APPLING
COFFEE
BACON
TELFAIR
DODGE
HAMILTON
SUWANNEE
LAFAYETTE
DIXIE
NASSAU
DUVAL
BAKER
UNION
CLAY
ST JOHNS
ALACHUA
PUTNAM
FLAGLER
LEVY
MARION
VOLUSIA
CITRUS
LAKE
SEMINOLE
HERNANDO
ORANGE
PASCO
BREVARD
Cape Canaveral
OSCEOLA
POLK
HILLSBOROUGH
MANATEE
HARDEE
INDIAN RIVER
OKEECHOBEE
ST LUCIE
HIGHLANDS
SARASOTA
DE SOTO
MARTIN
CHARLOTTE
GLADES
HENDRY
PALM BEACH
West Palm Beach
COLLIER
BROWARD
Cape Romano
DADE
Miami
Cape Sable
MONROE
Bimini Island

Figure 109.

SECTOR #1: Dare, Hyde, Beaufort, Pamlico, Craven and Carteret Counties, North Carolina

Sector 1 is located on the Pamlico and Core Sounds, which are formed by the offshore barrier islands Hatteras, Ocracoke and Core. The counties north of Carteret are unique in that the barrier islands, which are common along the entire eastern shore, are separated here by an expanse of water as much as 30 miles wide at some points. Beginning in Carteret County and southward, the barrier islands are closer to the mainland.

Fifteen thousand acres of land in Carteret County and 10,000 acres of water have been dedicated to the Cape Lookout National Seashore; and another 32,500 acres, in Hyde and Beaufort counties, comprise the Cape Hatteras National Seashore. Other notable environmental management areas include Mattamuskeet National Wildlife Refuge, Pea Island National Wildlife Refuge, Gull Rock State Wildlife Management Area, Fort Macon State Park, Croatan National Forest, Goose Creek Game Land, Cedar Island National Wildlife Regure, Dare Gameland, and Big Pocosin Game Land.

Sector #1, with its large forest and wetland areas, is largely rural. Dare, Hyde and Pamlico county have no urban population. Craven county is the most populous of the six counties. New Bern is its only urban center. Beaufort County was 24.9% urban. The town of Washington on the Pamlico River is its only urbanized area . Morehead City is the only urban center in Carteret County.

SECTOR #2: Onslow and Pender Counties, North Carolina

Onslow and Pender are largely rural counties, with as much as 50% of their land in wetlands and 79% in commercial forest areas. The entire coastline of these two counties is protected by a series of narrow barrier islands. The hinterlands of these islands are for the most part marshes which are separated from the drier mainland shore by an intracoastal waterway.

Approximately 20% of Onslow County is taken up by the Camp Lejeune U.S. Marine Reservation, which is located around the large natural bay created by the New River. Hammocks Beach State Park occupies 892 acres in Onslow County. Pender County is best known for its Holly Shelter Game Land and Angola Game Land which together occupy 76,000 acres of predominantly wetland areas.

Onslow County, although largely rural, owes its relatively high population of 103,126 to Camp Lejeune. Jacksonville is located near the naval reservation and is the county's only urban center.

SECTOR #3: New Hanover and Brunswick Counties, North Carolina

New Hanover and Brunswick Counties continue the pattern of swampy, forested coastal flatlands. Soils are generally of poor quality for farming. Approximately 78.6% and 46.2% of all lands in

Brunswick and New Hanover County, respectively, are in commercial forest. Here, as in other coastal counties, forests provide the raw materials for an extensive pulp, paper, and wood products industry. New Hanover County has less forest areas because it is more highly urbanized than the adjoining coastal counties. Wilmington, the primary city, owes its growth largely to its strategic port location on the Cape Fear River, 20 miles north of its mouth.

Lands under environmental protection or management are the Masonboro State Park on Masonboro Island in New Hanover County and the Eagle Island Game Land in Brunswick County. The excellent beaches along the coast of both counties are experiencing a growth in second home and low profit hotel/motel construction.

New Hanover County is the most highly urbanized of the North Carolina coastal counties. Sixty-nine percent of its 83,000 population is urban and located in the rapidly growing port city of Wilmington, the only North Carolina city along the coast which is classified as a regional center. The river front, from the northern city line of Wilmington southwards about six miles, is largely taken up by port facilities, warehousing and oil storage terminals.

Brunswick County is largely rural. Its only urban center is Southport at the mouth of the Cape Fear River. It is the site of a new nuclear power plant constructed in 1972 and a proposed chemical plant.

New Hanover County has nearly 100 manufacturing firms of which all but six are located in Wilmington. Forest products, cement and cement products, asphalt, textiles, processed foods, packaging, chemicals, fertilizers are the most commonly produced items. In Brunswick County, eight manufacturing firms produce textiles, cement, fish products, building materials, wood products, chemicals, and machine parts.

SECTOR #4: Horry and Georgetown Counties, South Carolina

Large land areas in Horry and Georgetown counties are wetlands and are well defined along the rivers which drain them. Two major rivers are the Santee and the Waccamaw.

Seventy percent of this little developed two-county sector is forested, 69% is commercial forest.

Environmental use or management areas along the coast are Huntington Beach State Park and Myrtle Beach State Park, totalling 2,812 acres. Five game management areas--Gapway Bay, Kilsock, Pee Dee, Biust, and Waccamaw--comprise another 49,367 acres. Of these, all but the Pee Dee Game Management area are owned by paper companies. Another large area, Hobcaw Barony (17,500 acres) on the Winyah Bay in Georgetown County, is owned by a private foundation and operated by

Clemson University for research and education in forest and resource management. Another 573 acres at Myrtle Beach are devoted to the South Carolina Agricultural Experiment Station.

SECTOR #5: Berkley and Charleston Counties, South Carolina

Berkley County is sparsely developed, with more than 83% of its land area forested and 14% of its land in farms. Although it has no coastline of its own, Berkley County was included in the coastal area analysis because it is part of the Charleston SMSA and for much of its length is no more than 10 miles from the ocean. It has two outlets to the sea, the Cooper and the Wando Rivers, which flow into Charleston Harbor.

Charleston County has large wetland and coastal marsh areas. Unlike Horry and Georgetown counties, whose beach hinterlands are wide and largely dry, Charleston County has wide marsh areas and an extensive system of marshes, estuaries and inlets created by a number of rivers which drain the inland swamps and meander toward the sea. These marshes make access to many of the beaches difficult.

Charleston County, which has substantial urban development, is only 50% covered with forest areas; 11.7% of its land is in farms. Large sections of Sector #5 have been designated as environmental use or management areas. These are the Francis Marion National

Forest which is also a game management area; the Cape Romain National Wilderness Area and Edisto Beach State Park.

Charleston County, with 82% of its 247,650 population living in the cities of Charleston, Mount Pleasant and James Island, is the most populous and urban of South Carolina's coastal counties. Berkley County has less than 1/4 the population of Charleston County and its population density is substantially lower: 51 per square mile to Charleston County's 264 persons per square mile. Berkley County's population is only 45.1% urban and it has two urban centers, Monck's Corner and Goose Creek.

SECTOR #6: Colleton, Beaufort and Jasper Counties, South Carolina

Sector #6 is characterized by its vast system of coastal rivers, marshes, waterways and islands. Most of the sector is undeveloped and inaccessible except by boat. One exception is Beaufort, which lies at the center of a large grouping of marshy islands: St. Helena, Ladies, Port Royal and Parris. The area includes two miliary reservations. The northeastern end of Helena Island contains the 5,000 acre Hunting Island State Park.

Numerous rivers converge in this area; the South Edisto, Combahee Bull, Coosaw, Beaufort, Broad, Checkhessee, Colleton and May rivers, as well as countless streams and creeks.

The Savannah National Wildlife Refuge is a notable environmental management area located on the Savannah River some 15 miles from its mouth.

Colleton, Beaufort and Jasper counties are largely rural. Beaufort County, with a density of 88 persons per square mile, owes its population of 51,136 largely to the Marine bases near Port Royal and Beaufort, which are the only urban settlements in the county. Twenty-three percent of Colleton's 27,622 population is urbanized in the county's only urban center, Waterboro. Japser County, where the population is just under 12,000, is rural.

SECTOR #7: Chatham and Bryan Counties, Georgia

Chatham and Bryan counties are similar to Beaufort and Jasper to the north. Broad expanses of marsh, waterways, and sounds characterize the coast. The City of Savannah is approximately 15 miles inland from the sea separated from it by Wilmington and Tybe Islands. Orginally built on dry hummocks, Savannah has had to expand by the draining and filling of wetlands.

Outside metropolitan Savannah, development in both counties is exceedingly sparse. A large part of Bryan County is occupied by the Fort Stewart Military Reservation and therefore, excluded from private development. The rivers which empty into the tidal marshlands along the coast are the Savannah, Wilmington, Ogeechee, and Medway River.

Environmental management areas include the Fort Pulaski National Monument, Savannah National Wildlife Refuge, and Tybee National Wildlife Refuge.

Chatham County is the most highly urbanized of the Georgia coastal counties. Its population is 187,767 located in Savannah, three surrounding other municipalities and various unincorporated urban areas. The city comprises 37 of the 422 square mile county area. Most of the older developed portions south of the river are on hummocks of well-drained soils.

Bryan County, south of Savannah, is rural with large areas of marsh and swampland. More than 30% of the county is occupied by the Fort Stewart Military Reservation.

SECTOR #8: Liberty, McIntosh, Blynn, Camden and Charlton Counties, Georgia

Eighty percent of these counties is forested. Only some 8% of the land area is in farms. Brunswick in Glynn County is the only city of any size, with the remaining counties sparsely populated.

Four state parks are located in the area: Crooked River, Santa Maria and Stephen C. Foster. Other environmental management areas include the Altamaha Waterfowl Public Hunting Area, Fort Frederica National Monument, Blackbeard Island National Wildlife Refuge, Harris Neck National Wildlife Refuge, Okefenokee National Wildlife Refuge. Cumberland Island, one of the largest barrier islands located opposite the Camden County mainland, has been proposed as a national seashore.

The major rivers which flow into the extensive tidal marsh areas are the Sapelo, Altanaha, Turtle, Satilla, and Crooked Rivers.

The combined population of Sector #8--Liberty, McIntosh, Glynn, Camden, and Charlton counties--is less than 100,000. Glynn County, with a 1970 population of 50,373, contains the city of Brunswick, the most important urban center on the Georgia coast outside of Savannah.

Approximately 30% of Liberty County is occupied by the Fort Stewart Military Reservation in the northwest, effectively precluding civilian development of the area. It accounts for a large share of the 17,569 population. Hinesville is the only urban area. Only 4.35% of the total county land area is developed.

McIntosh County is rural with a population of 7,371 persons. The largest town is Darien, a shrimp and crab processing town on Cathead Creek. Of the total county land area, 8.2% is developed.

Glynn County occupies 16,896 acres, of which 12,610 are marsh and water. Other settlements in the Brunswick area are Saint Simon's

Island, Sea Island and Jekyll Island, which have recently been developed or redeveloped as year-round recreation communities; 7.35% of the county's total area is developed. The Blythe Naval Reservation occupies 10,030 acres of land to the west of Brunswick.

Only 149 acres are currently used for industrial purposes, primarily along the Turtle River and Southern Railroad; 17,462 acres are zoned for industrial uses. Of these, 11,091 acres are in marsh and low lying land not suitable for industrial use. Of the remaining 6,371 acres, 4,000 acres are available for industrial uses.

Camden County's population is 11,334. A single urban center, St. Mary's, is located on the St. Mary's River which forms the boundary line between Georgia and Florida. Only 7.35% of the total area of the county is developed.

Cumberland Island, a large barrier island stretching from St. Andrews Sound south to the mouth of the St. Mary's River, is being proposed as a National Seashore. On the island itself only minimal development would be permitted according to preliminary proposals. However, substantial tourism development is expected to occur on the mainland.

Charlton County is rural, with a population of less than 6,000.

SECTOR #9: Nassau, Duval and St. Johns Counties, Florida

Eighty-three percent of Nassau County is covered by forest which provides the basis for its primary industry--pulp and paper. Of its total land area, 15.7% was in farms in 1969. Similar statistics for Duval and St. Johns counties are 60% and 75% forest area and 15.2% and 17.0% farming, respectively. Development is sparse except for the concentration in the heavily populated Jacksonville area and the resort oriented urban centers of St. Augustine, Jacksonville Beach, and Fernandina Beach. Tidal marshes, islands and estuaries are found extensively between the barrier islands and the mainland north of the St. Johns River.

The western third of Nassau County contains the forestry and game management areas. The estuarine northeast portion of the county is within a hurricane flood zone and unsuitable for development. The St. Mary's and the St. Johns Rivers, their tributaries, coastal marshlands, and the ocean three miles offshore above the St. Johns River have been established as Florida Aquatic Preserves which prohibit development which will harm the natural environment of the aquatic system. Large areas between Lofton Creek and the coastal marshes and smaller areas to the west have been established by the Florida Coastal Plains Coordinating Council as suitable for future intensive development.

Two State parks are Fort Clinch on the northern end of Amelia Island and Little Talbot Island State Park on the island of that name.

Nassau County, Florida, with its population of 60,626 is only 33.7% urban; it is largely forest interspersed with swamp areas. Its only urban center is Fernandina Beach, located at the northern end of Amelia Island. The island, which is approximately 15 miles long, is accessible by car for most of its length and well known for its fine ocean beaches. One of the most recent developments there is the Amelia Island Plantation resort communities which have been built recently on the larger barrier islands in Georgia and South Carolina.

Duval County is the most populous of the coastal counties between Hatteras and Canaveral. Its population is 528,865, of which 97.9% is urban. Jacksonville is a regional urban center and a major port whose shipping tonnage exceeds 11 million short tons per year.

Industrial sites are located primarily along the northern and western shores of the St. Johns River along the Seaboard Air Rail Line and the Southern and the Atlantic Coast Line railroads, within the limits of the Jacksonville Beltline. Future industrial development is being encouraged to expand to the south along I-95, Phillips Highway and Florida East Coast Railway.

St. Johns County has a population of 30,727, of which 40.2% is urban. St. Augustine, located on the Mantanzas River and the Intracoastal Waterway is the largest city. Much of the area behind the coastal beachfront is wooded and swampy.

The coast and parts of the St. Johns River are readily accessible; recreation and tourism are important sectors of the economy, encouraged by the historic attractions of St. Augustine.

SECTOR #10: Flagler, Volusia and Brevard Counties, Fla.

Flagler, Volusia, and Brevard Counties are 84%, 68%, and 19% covered by forests, respectively. The corresponding figures for the proportion of land in farms are 29.4%, 32.8% and 35.3%. Intensive development in these counties has occurred only in the ocean resorts and in Deland to the west.

Large portions of the counties are considered marginal lands unsuitable for development. Along the coast are areas in hurricane flood plain zones. Beginning in central Volusia County, broad coastal marsh areas begin to reappear between the barrier islands and the mainland. In Brevard County, the greater part of Merrit Island has been designated as a wildlife refuge, but this has not precluded its use for aerospace installations of the John F. Kennedy Space Center. The area bounded by the Indian River to the island and east of the Intracoastal Waterway has been designated a Florida Aquatic Preserve.

Flagler County, which contains large areas of swamp land, is sparsely populated. Its density is only 9 persons per square mile and its total population was below 5,000 in 1970. Its beaches are still sparsely developed except for Flagler Beach, in the southeastern corner of the county, which adjoins Ormon Beach - a part of the Daytona Beach complex.

Volusia County is well known for its extensive tourism development and beaches; Daytona Beach, Ormond Beach, and New Smyrna Beach form a continuous belt of tourist and second home developments along the coast. The highest point of concentration is at Daytona Beach. Another important urban center is Deland, in the western section of the county.

Brevard County is noted for the Kennedy Space Center and related industries at Cape Canaveral. Immediately to the south of Cape Canaveral are the large resorts which serve as the residential and service areas for the huge aerospace complex.

SECTOR #11: Indian River, St. Lucie, Martin, Palm Beach, Broward, and Dade Counties

Florida's southeast is the State's leader in nearly every measure of economic activity and is the most populous region. This area has been the State's fastest growing region over the past decade and the influx of new residents continues at a high rate. The density of population in Dade, Broward, and Palm Beach are significantly increasing. Land is scarce throughout the coastal area.

The three largest counties, Dade, Broward, and Palm Beach comprise Florida's "Gold Coast". Urban development is intensive along the coast and extends from the Palm Beach area through Dade County. Continued influx of population and business establishments is expected. Palm Beach County is coextensive with the West Palm Beach SMSA. It is the least developed of the East Coast metropolitan counties and has a very high growth potential. Martin, St. Lucie, and Indian River counties, presently less intensively developed than the "Gold Coast", can expect to receive population "spill over" from the "Gold Coast" as density increases in the latter area.

The Loxahatchee National Wildlife Refuge is in Palm Beach County. Broward County contains the Everglades Wildlife Management Area, and the Everglades National Park is in Dade County.

(2) Recreation Resources

The Atlantic Coast is richly endowed with natural and manmade recreation resources. This richness both in terms of diversity and abundance makes it virtually impossible to catalogue completely the resources or to develop a regional report on a consistent basis. For these reasons, the discussions of recreation resources attempt to indicate the values and distinctive characteristics of the three regions and do not provide nor attempt to provide a base for statistical comparisons. The "Northeast" refers to both the New England or North Atlantic States as well as the Middle Atlantic States. The South Atlantic (southern coastal States from the Carolinas) is discussed separately. The information presented in this section on the Northeast is drawn in part from Chapter 12 of the Coastal and Offshore Environmental Inventory: Cape Hatteras to Nantucket Shols, Complement Volume, Marine Publication No. 3, University of Rhode Island. The information presented Recreation in the South Atlantic coastal area is taken from "A socio-Economic Environmental Baseline Summary for the South Atlantic Region between Cape Hatteras, N.C. and Cape Canaveral, Fla.," prepared by Planners Incorporated.

The use of recreational resources in the Northeast region has become very heavy, brought on by easy access to most inland and coastal recreational facilities, ever increasing mobility in an expanding population, and larger disposable incomes. Recreational resources range rom extremely plentiful in northern New England to very deficient in e highly populated Long Island area. The following table gives estimates the summer days of participation in 1970 for seven major outdoor creation activities. Swimming is the most popular water recreation tivity in the Northeast. The beaches in Virginia, on the Delmarva ninsula, the Jersey shore, Long Island and Cape Cod. attract millions persons. Only 11 percent of the total North Atlantic shoreline in public hands for recreation. Recreational boating occurs primarily the protected areas of estuaries and embayments, waterways such as e intracoastal waterway, lakes, reservoirs, and other inland flat ters of adequate surface area. The total water surface in the rtheast is shown in the table to be over seven thousand square les, and there are 6 million acres of protected recreational boating ters in the region. Although there is adequate recreational water rface, the shoreline facilites are congested and in short supply. rests and state parks provide additional recreational opportunties the Northeast. Only one-tenth of forest acreage is maintained in blic ownership, and the forest environment thus provides the major se for future development of Federal, State and private recreation cilities in the region.

[redacted]

Table 37. TYPES OF RECREATION SHORELINE BY STATE (miles)

State	Total Shore	Bluff Shore	Marsh Shore	Be~~n~~ach	Public Recreational Shore	Restricted Shore
Atlantic Coast						
Maine	2,612	2,520	69	23	34	--
N. Hampshire	25	9	9	7	3	--
Massachusetts	649	288	121	240	12	6
Rhode Island	188	145	4	39	8	10
Connecticut	162	61	29	72	9	--
New York	669	249	224	196	35	--
New Jersey	366	33	232	101	18	15
Delaware	97	--	56	41	9	9
Maryland	1,368	912	416	40	3	113
Virginia	692	118	414	160	2	26
N. Carolina	1,326	260	781	285	139	42
S. Carolina	522	--	360	162	9	10
Georgia	385	--	293	92	5	--
Florida	900	262	331	307	50	32

Source: Shoreline Recreation Resources of The United States Washington, D.C.: A Report to the Outdoor Recreation Resources Review Commission by George Washington University, 1962.

[a] This table does not include shoreline not useful for recreation.

Activities, Northeast State, South Atlantic States, and U.S., 1970[a]

Region and Characteristic	% of Pop.	Recreation Days (1000's)	Days Per Person
Boating			
U.S.	24.2	388,212	2.5
Northeast[b]	22.7	89,202	2.4
South Atlantic	20.1	57,330	2.4
Swimming			
U.S.	43.6	1,423,010	9.2
Northeast	49.5	382,462	10.4
South Atlantic	39.0	211,265	9.0
Wildlife & Bird Photography			
U.S.	2.9	37,828	0.2
Northeast	3.0	11,652	0.3
South Atlantic	2.1	4,104	0.2
Fishing			
U.S.	28.4	514,669	3.3
Northeast	20.2	83,898	2.3
South Atlantic	29.4	87,353	3.7
Camping			
U.S.	19.9	354,769	2.3
Northeast	13.3	65,721	2.4
South Atlantic	13.9	34,878	1.5

[a] Population 12 years of age and older.

[b] The Northeast is here defined to include both the New England and Mid-Atlantic Census Divisions (including Pennsylvania).

Table 38, cont.

Nature Walks			
U.S.	17.3	337,092	2.2
Northeast	17.3	81,078	2.2
South Atlantic	14.3	49,253	2.1
Picnicking			
U.S.	47.6	479,993	3.1
Northeast	47.5	122,515	3.3
South Atlantic	39.5	61,387	2.6

Source: U.S. Department of Interior, Bureau of Outdoor Recreation. The 1970 Survey of Outdoor Recreation Activities, Washington, D.C., 1972.

Total Water Surface in the NAR

Surface Type	Area (Sq. miles)
Small Surface (under 40 acres)	764.0
Large and Intermediate Surfaces (over 40 acres)	6,610.9
Total	7,374.9

South Atlantic Region

Numerous environmental management areas are located along the coast, effectively placing approximately 1.4 million acres of land under environmental controls and excluding much of it from future development. They include national and state parks, national seashores and forests, wildlife refuges and game management areas. Not only do these environmental management areas preserve large areas of land from development pressures; they also figure increasingly in the growing tourism industry. The prime natural attractions of the coast are its miles of sandy beaches, waterways and estuaries which attract swimmers, boaters, and sports fishermen; primarily in the summer months.

While many fine beaches have yet to become tourist attractions due to lack of access facilities, and undeveloped markets, others, such as the Grand Strand and Myrtle Beach in South Carolina, are drawing vacationers from across the country. The Grand Strand already boasts more than 40,000 tourist beds. Island year-round resort communities are becoming increasingly popular all along the coast ranging from exclusive low profile, low density development to high-rise condominium projects. There is, however, increasing public pressure to maintain off-shore islands in their natural state as public, limited use parks and to limit tourism development to the mainland. Either way, the untapped resources for tourism are so great that tourism was selected by the Coastal Plains Regional Commission as the third of six major target areas for development after industrial development, education and manpower training. There are over 600 miles of ocean beach along the barrier islands and parts of the mainland which are within the reach of the major cities of the eastern and southeastern regions of the U.S. Of these, less than 300 miles are currently accessible by road.

Table 39. NUMBER OF AMUSEMENT AND RECREATION SERVICES BY STATE FOR COASTAL AND INLAND AREAS

Area	1948[a]	Percent[b]	1958	Percent[b]	1967	Percent[b]	1958-1967 Percent Change
United States	50,347		74,696		96,029		29
North Atlantic Region:[c]							
Coastal	5,502	59	10,026	65	12,102	63	21
Inland	3,773	41	5,510	35	6,961	37	26
Maine:							
Coastal	201	52	277	57	286	50	3
Inland	188	48	211	43	282	50	34
New Hampshire:							
Coastal	65	24	80	25	137	32	71
Inland	203	76	242	75	297	68	24
Massachusetts:							
Coastal	998	71	1,874	76	2,126	75	13
Inland	404	29	576	24	696	25	21
Rhode Island:							
Coastal	287	-	411	-	438	-	7
Inland	0	-	0	-	0	-	-

[redacted]

Table 39, cont.

Area	1948[a]	Percent[b]	1958	Percent[b]	1967	Percent[b]	1958-1967 Percent Change
Connecticut:							
Coastal	460	68	675	68	826	63	22
Inland	216	32	313	32	474	37	51
New York:							
Coastal	2,887	62	5,487	68	6,744	67	23
Inland	1,800	38	2,589	32	3,322	33	28
New Jersey:[d]							
Coastal	604	39	1,222	44	1,545	45	26
Inland	962	61	1,579	56	1,890	55	20

Source: U.S. Department of Commerce, Bureau of Census, Census of Business, 1948: Vol. II; 1958: Vol. III; 1967: Vol. V.

[a] The figures for 1948 include motion pictures; 1958 and 1967 figures exclude motion pictures.

[b] Each state is divided into coastal and inland counties. The figure in this column gives coastal and inland counties as a proportion of the state.

[c] The inland totals for the North Atlantic region include coastal counties south of Sandy Hook, New Jersey.

[d] The coastal counties of New Jersey include only the six counties north of Sandy Hook. The inland counties include all others.

Table 40.

ACRES AND SITES OF PUBLIC AND PRIVATE CAMPGROUNDS, BY COUNTY, 1972

State and County	Public Campgrounds		Private Campgrounds		Total Campgrounds	
	Acres	Sites	Acres	Sites	Acres	Sites
NE[a]	9,386	2,542	6,722	10,513	16,109	13,055
hington	973	212	709	387	1,682	599
cock	444	1,209	688.5	1,380	1,132.5	2,589
do	430	75	131	280	561	355
x	5,004	219	200	370	5,204	589
coln	430	30	375	497	805	527
Sagadahoc	-	-	1,103	942	1,103	942
Cumberland	2,070	690	2,007	1,604	4,077	2,294
York	35	107	1,509	5,053	1,544	5,160
NEW HAMPSHIRE[a]	5,530	200	1,979	3,035	7,509	3,235
Strafford	-	-	950	961	950	961
Rockingham	5,530	200	1,029	2,074	6,559	2,274
MASSACHUSETTS[a]	19,227	1,739	3,183	4,976	22,410	5,715
Essex	3,391	740	146	250	3,537	990
Middlesex	-	-	80	80	80	80
Suffolk	-	-	-	-	-	-
Norfolk	-	-	28	47	28	47
Plymouth	12,420	242	1,961	1,336	14,381	1,578
Barnstable	2,341	630	501.5	2,313	2,842.5	2,943
Nantucket	-	-	-	-	-	-
Dukes	-	-	153	508	153	508
Bristol	1,075	127	313	442	1,388	569

Table 40, cont.

State and County	Public Campgrounds Acres	Public Campgrounds Sites	Private Campgrounds Acres	Private Campgrounds Sites	Total Campgrounds Acres	Total Campgrounds Sites
RHODE ISLAND[a]	3,208	961	1,736	1,414	4,944	2,375
Newport	-	-	-	-	-	-
Bristol	-	-	-	-	-	-
Providence	100	40	1,269	532	1,369	572
Kent	-	-	50	25	50	25
Washington	2,208	921	417	857	2,625	1,778
CONNECTICUT[a]	5,599	1,332	1,247	1,896	6,846	3,228
New London	1,195	676	852	1,351	2,047	2,027
Middlesex	2,588	490	385	540	2,973	1,030
New Haven	1,816	166	10	5	1,826	171
Fairfield	-	-	-	-	-	-
NEW YORK[a]	2,454	552	28	3,704	2,482	4,256
Suffolk	2,454	552	28	3,704	2,482	4,256
Nassau	-	-	-	-	-	-
Westchester	-	-	-	-	-	-
Rockland	-	-	-	-	-	-
New York City	-	-	-	-	-	-
NEW JERSEY[a]	1,001	53	-	-	1,001	53
Bergen	-	-	-	-	-	-

Table 40, cont.

tate and County	Public Campgrounds Acres	Public Campgrounds Sites	Private Campgrounds Acres	Private Campgrounds Sites	Total Campgrounds Acres	Total Campgrounds Sites
assaic	-	-	-	-	-	-
udson	-	-	-	-	-	-
ssex	-	-	-	-	-	-
nion	-	-	-	-	-	-
iddlesex	1,001	53	-	-	1,001	53

ource: Compiled from Table 22-26 of the Appendix.

Data for states includes coastal counties only.

Table 41.

Recreational Resources - South Atlantic

North Carolina

Cape Lookout National Seashore	Carteret County 15,000 acres land 10,000 acres water
Cape Hatteras National Seashore	Hyde and Beaufort Counties 32,000 acres
Mattamuskelt National Wildlife Refuge	Hyde County 50,178 acres
Pea Island National Wildlife Refuge	Dace County 31,580 acres
Swan Quarter National Wildlife Refuge	Hyde County 39,938 acres
Gull Rock State Wildlife Management Area	Hyde County 18,856 acres
Fort Macon State Park	Carteret County 390 acres
Croatan National Forest	Craren County 152,351 acres
Goose Creek Game Land	Pamlico and Beaufort Counties 7,099 acres
Cedar Island National Wildlife Refuge	Carteret County 12,526 acres
Dace Gameland	Dace County 155,134 acres
Big Pocosin Game Land	Beaufort and Crarein Counties 24,115 acres
Hammocks Beach State Park	Onslow County 892 acres

Table 41, cont.

Holly Shelter State Game Land and Angola Game Land	Pender County 76,000 acres
Masonboro State Park	New Hanover County 441 acres
Eagle Island Game Land	Brunswick County 2,000 acres
South Carolina	
Huntington Beach State Park and Myrtle Beach State Park	Horry and Georgetown Counties 2,812 acres
Gapway Bay, Kilsock, Pee Dee, Biust, and Waccamaw game areas	Horry and Georgetown Counties 49,367 acres
Hobcaw Bacony	Georgetown County 17,500 acres
Francis Marion National Forest	Charleston and Berkley Counties 246,212 acres
Cape Romain National Wildlife Refuge	Charleston County 55,066 acres
Cape Romain Wilderness Area	Charleston County 28,000 acres
Edisto Beach State Park	Charleston County 1,255 acres
Savannah National Wildlife Refuge	- 7,229 acres
Georgia	
Fort Polaski National Monument	- 5,517 acres
Savannah National Wildlife Refuge	- 6,676 acres
Tybee National Wildlife Refuge	- 100 acres
Crooked River	Camden Co. 500 acres

Table 41, cont.

Jekyll Island	Glynn Co. 11,000 acres
Sante Maria	Camden Co. 65,000 acres
Stephen C. Foster	Charlton Co. 80,000 acres
Attamaha Waterfowl Public Hunting Area	McIntosh Co. 30,000 acres
Fort Frederica National Monument	Glynn Co. 210 acres
Blackbeard Island National Wildlife Refuge	McIntosh Co. 6,617 acres
Harris Neck National Wildlife Refuge	Liberty and McIntosh Counties 2,687 acres
Okenfenokee National Wildlife Refuge	Charlton Co. 341,000 acres
Wolf Island National Wildlife Refuge	McIntosh County 538 acres
Cumberland Island	- -
Florida	
Fort Clinch State Park	Amelia Island -
Little Talbot Island State Park	Amelia Island
Anastasis State Park	St. John's County
Butter State Park	St. John's County
Faver-Dykes State Park	St. John's County
Washington Oaks Gardens	Flaglev County

Table 41, cont.

Flagev Beach	Flaglev County
Tomoka State Park	Wolusia County
Merritt Island National Wildlife Refuge	Brevard County
Pelican Island National Wildlife Refuge	Indian River County
Jack Island State Park	St. Lucie County
Dickinson State Park	Martin County
Birch State Park	Broward County
Cape Florida State Park	Dade County
Pennekamp Coral Reef State Park	Dade County
Everglades National Park	Dade County

(3) Transportation

Major Ports and Shipping, North Atlantic

Maine

Searsport. Searsport is located at the head of Penobscot Bay, which has an average depth over 60 feet. About a mile separates the harbor facilities from the deep water of the bay, and there is a 35-foot access channel. The 1970 commerce was 1,010,000 tons.

Rockland. Rockland is one of many shallow-draft harbors along Penobscot Bay. It lies in a natural bight protected by breakwaters, and while the natural depths lie between 12 and 18 feet, a 13-foot minimum depth is maintained. The 1970 commerce was about 30,000 tons.

Eastport-Cobscook Bay. Cobscook Bay is almost inclosed by land, and Eastport ranks first among its half dozen ports. Eastport has offshore depths of about 35 feet and the Bay proper is about 14 feet deep. The 1970 commerce was 36,000 tons.

Portland. At Portland, an inner and outer harbor have been developed on the southern coast of Casco Bay. The inner harbor is located along the Fore River, which has been improved to provide for vessel traffic of 35-foot draft. The 1970 commerce was 30,000,000 tons.

New Hampshire

Portsmouth. Portsmouth is located two miles from the Atlantic Ocea on the Piscataqua River. The river channel has been improved to a depth of 35 feet, with an average width of 400 feet (one-way traffic) for a distance of 6 miles. The 1970 tonnage was 2,190,000 tons.

Massachusetts

Boston. The Port of Boston consist of an outer harbor formed and protected by islands and peninsulas, and an inner harbor formed by the confluence of several rivers. Its access channel is 1,200-1,500 feet wide, at depths ranging from 35 to 40 feet, and passes from the Atlantic Ocean through the outer harbor into the inner harbor as far as the mouths of each of the rivers. Thirty-five-foot channels extend into the rivers. The 1970 tonnage was 26,870,000 tons.

Salem. Salem is located just north of Boston, and its 1.5-mile-long access channel is 32 feet deep and from 300 to 400 feet wide. Channels ranging in depth from 5 to 10 feet are maintained to various wharfs and yacht clubs in other areas of the port. The 1970 commerce was 1,250,000 tons.

Fall River. Fall River is on the northeast side of Narragansett Bay, about 18 miles from Providence, and has an existing access channel 35 feet deep and from 400 to 1,100 feet wide. Commerce in 1970 was 4,330,000 tons.

New Bedford. The cities of New Bedford and Fairhaven form a port in the mouth of the Achshnet River. Its 5-mile-long access channel is 30 feet deep and 350 feet wide. The 1970 commerce was 615,000 tons.

Others. Boston, Providence, Fall River, Salem and New Bedford account for more than 95% of the waterborne commerce in Area 9. Nine other ports account for an additional 20,000 to 300,000 tons each.

Major Interstate Highways, North Atlantic

Major interstate highways serving the coast North Atlantic area are: Route 95 which links Houlton, Benyor, and Portland, Maine with Portsmouth, New Hampshire, and Boston, Massachusetts; Route 93 which links Boston, Massachusetts with central and northwestern, New Hampshire; Route 495 which circles Boston fron Newburyport to North Attleboro.

Railroad System, North Altantic

Although rail lines exist from northern Maine to Boston, Massachusetts in the North Atlantic area, only freight service is provided north of Newburyport, Massachusetts. Antrak passenger routes link Boston, Massachusetts with New York, New York. Freight lines connect Portland, Maine with northern and central Maine, Canada, and Boston, Massachusetts. Additional freight wervice is provided from Boston, Massachusetts to Buffalo, New York City, New Hampshire, Vermont, and Western Massachusetts.

Aviation Routes, North Atlantic

The only major airport in the North Atlantic are is Boston's Logan Airport. However, iar transportation for cargo and passengers does exist for important cities in Maine and New Hampshire.

Mid-Atlantic Ports and Shipping

Rhode Island

Providence. The Port of Providence has been developed along a 2.5-mile section of the Providence River about 10 miles from and 600 feet wide. The 1970 commerce was 9,870,000 tons.

Connecticut

New Haven. The access channel at New Haven is 35 feet deep and protected by breakwaters. The 1970 commerce was 11,600,000 tons.

Bridgeport. The Bridgeport access channel is 35 feet deep, with branch channels having depths of 7 to 30 feet. The 1970 commerce was 3,800,000 tons.

Norwalk. Norwalk is 11 miles south of Bridgeport on Long Island Sound. Its access channel is 10 feet deep (12 feet at the mouth). The 1970 commerce was 1,100,000 tons.

Stamford. Stamford is 40 miles from New York and 10 miles form Norwalk in the mouth of the Rippowam River. Its access channel is 15 feet deep (18 feet deep at the mouth). The 1970 commerce was 1,020,000 tons.

New York

All total in 1972 commerce amounted to 198,843,000 tons for the ports of New York.

East River. The East River connects Long Island Sound with Upper New York Bay. It is a 16-mile channel, generally 35 feet deep an 1,000 feet wide. It passes through the heart of New York, with spur channels designed for barge traffic leading into adjacent creeks and rivers, such as the Harlem River. From Upper New York Bay to the Brooklyn Naval Yard on the East River, a distance of 2.5 miles, the channel has a depth of 40 feet.

Upper New York Bay. Upper New York Bay is generally 40 or more feet deep because of the extensive channel and anchorage development throughout. The Portion located in Area 13 includes the Buttermilk, Red Hook and Bay Ridge Channels, which are all 40 feet deep.

North Shore of Long Island. Long Island Sound is more than 100 miles long. Along the western portion of the Island's north shore, there are about a dozen large bays which have natural depths of 20 feet. Access channels to these bays have depths generally from 9 to 12 feet.

South Shore of Long Island. The South Shore is formed by a narrow barrier beach extending the length of the Island, and broken in a half dozen places by tidal inlets. Behind this barrier beach, there are five rectangular bays, generally less that 5 feet deep, but interconnected by a dredged 6-foot channel.

New Jersey

Hudson River. The Hudson River below the George Washington Bridge is included beacuse most of the commerce is now handled through New Jersey. The Federal project provides a 40-foot deep channel for the full width of the river extending from Upper New York Bay to 59th street. A 2,000-foot wide section of this project has been deepened to 45-48 feet deep. Above 59th street, a natural channel extending 600 feet wide and 32 feet deep is a part of the Hudson River, N.Y.C., to Waterford project. A channel to the Weehawken-Edgewater waterfront is 30 feet deep and 750 feet wide.

Newark Bay. Both tankers and dry cargo vessels with drafts exceeding the project depth of 35 feet were reported to have entered the waterway in 1970.

Pennsylvania

Philadelphia. Gloucester City, Camden, and Philadelphia include 22 miles of port-developed waterfront on the Delaware River known as the Ports of Philadelphia.

The Schuylkill River empties into the Delaware at Philadelphia and is extensively developed for commercial navigation for about 6 miles. The present project depth is 33 feet.

Delaware

Wilmington. The Port of Wilmington on the Delaware River has an access channel with a 40-foot depth. The 1970 commerce totalled 2,761,000 tons.

Maryland

Baltimore. The Port of Baltimore is similar to a long stemmed "Y" in shape.

District of Columbia

Potomac River. The Potomac carries a large sediment load and is subject to shoaling in many places. Washington, D. C. and Piney Point, Maryland are the major ports on the river. Where necessary, the natural channel has been improved to provide a waterwqy to Washington, D. C. that is 24 feet deep and 200 feet wide.

Virginia

Norfolk. A 5-mile long channel, which is 45 feet deep and 800 feet wide, extends from the entrance channel at Hampton Roads to the deep water of the James River.

Major Interstate Highways, Mid-Atlantic

Interstate highways serving the Mid-Atlantic area includes route 195 which connects New Bedford, Massachusetts, to Providence, Rhode Island; route 95 which links Boston with Providence, New London, New Haven Bridgeport, New York City, Newark, Trenton, Philadelphia, Wilmington, Baltimore, Washington, D. C., and Richmond. The large population along the coast from Boston to Washington, D. C. has resulted in the creation of a complex road network to serve it. Additional interstate highways serving New York City and vicinty, includes routes 278, [illegible], 80, 87, 279, 287, 295, 495, 684, 678. Major interstate highways between Newark, New Jersey and Philadeophia, Pa. are routes 95, 295, 76, and 676. In the Baltimore area, route 695 encircles the city, route 83 runs North to Pennsylvania; and route 70 N heads to West Virginia. Interstate 495 encircles Washington, D. C. and is served by 70 S (to Maryland) and 66 (to Virginia). Route 64 connects with 95 in Richmond, Virginia and serves Newport News, and Charlottesville, Virginia. Route 85 branches from 95 south of Richmond and connects with Durham, North Carolina.

Railroad System, Mid-Atlantic

Railroad passenger service in the Mid-Atlantic runs from Boston through Coastal Rhode Island and Connecticut, New York City, Newark, Trenton, Wilmington, Philadelphia, Baltimore, Washington, D. C., Newport News, and Norfolk. Major freight lines, in addition, connect Baltimore, New York City, and Boston with Buffalo, Washington with Pittsburgh, Charleston, Jacksonville, and Atlantia, and Norfolk with Atlanta, Charleston, and Jacksonville.

Aviation Route, Mid-Atlantic

Major airports of the Mid-Atlantic area include Providence, the three airports at New York (Laguardia, Kennedy, and Newark), Philadelphia, the two airports at Washington (Dulles and National), and and Norfolk. Additional cargo and passenger service exists for a large number of major cities in the area.

Major Ports and Shipping, South Atlantic

North Carolina

Morehead City. The port of Morehead City is on a peninsula extending easterly from the mainland between Bogue Sound and Calico Creek.

The deepwater approach from the Atlantic Ocean to the port is via a dredged channel across the bar and through Beaufort Inlet between Bogue and Shackleford Banks.

Wilmington. The port of Wilmington principal waterfront facilities are along the city's waterfront on the east banks of the Cape Fear and northeast Cape Fear Rivers; the junction of the 2 rivers is at Wilmington, about 28 statute miles above the mouth of the Cape Fear River.

The Corps of Engineers maintains a 40 foot channel from the ocean to Southport and 38 feet from Southport to Wilmington Harbor. Above Wilmingto there is a 25 foot channel for 2.9 miles to Navassa and 12 feet from there for 30 miles to Acme. The 1970 commerce was 5,530,000 tons.

South Carolina

Georgetown. The port of Georgetown is located along the north bank at the mouth of the Sampit River, which empties into the head of Winyah Bay from the northwest.

Beaufort. The Corps of Engineers maintains a bar channel 35 feet deep and 400 feet wide through Beaufort Inlet, then an inner channel 35 feet deep and 300 feet wide. The 1970 commerce was 1,364,000 tons.

Charleston. The port of Charleston is on a peninsula at the confluence of the Cooper River on the east and the Ashley River on the west. The rivers flow into the bay known as Charleston Harbor.

The deepwater entrance from the ocean to the port is via a 35 foot dredged channel between 2 stone jetties lying outside Sullivans Island on the northeast and Morris Island on the southwest. The 1970 commerce was 6,875,000 tons.

Georgia

Savannah, Savannah is located on the right bank of the Savannah River, about 15 miles from the Atlantic Ocean. Savanah is the second lartest city and the chief port of the State. The 1970 commerce was 6,811,000 tons.

Burnswick. The port of Burnswick is 82 nautical miles north of Jacksonville, Fla., and 104 nautical miles south of Savannah, Ga.

The harbor includes a 32 foot dredged channel across the ocean bar to the entrance of St. Simon Sound, a natural channel through the entrance between St. Simon Island on the north and Jekyll Island on the south, and channels in St. Simon Sound, Brunswick River, Turtle River, East River, Academy Creek, Back River, and Terry Creek. The 1970 commerce was 1,053,000 tons.

Major Interstste Highways, South Atlantic

Route 95 continues from Richmond to Fayetteville, Florence, Savnnah, Jacksonville, and Miami. Route 26 runs from Charleston, S.C. to Columbia, and Interstate 10 heads from Jacksonville to New Orleans.

Railroad System, South Atlantic

Railroad passenger lines extend from Norfolk to Jacksonville and Miami. Freight lines also service the major shipping ports in North and South Carolina, Georgia, and Florida connecting them with Atlanta, Jacksonville, Miami, and Norfolk.

Aviation Routes, South Atlantic

The only major airports in the South Atlantic area are Jacksonville and Miami, although passenger cargo service is provided to a number of other cities along the coast.

(4) Commercial Fisheries - Atlantic Coast

The following sections present data on the commercial fisheries industry in the Atlantic states. Included are figures as to total volume and value of fishery landings, important species landed, number of fisherman, value of processed fish products, and the number of processing and wholesaling establishments and their employment. Figures for total volume and value of fish landings are available for 1973. Detailed breakdowns of catch by species, however, are available only through 1971. The data is taken from the National Marine Fisheries Service's publications of current fisheries statistics.

1. Maine

In 1973, the total volume of fisheries landings in Maine was 143.3 million pounds with a value of $43.1 million. The 1973 landing were about 51% less in volume and 114% greater in value than 1960 fish landings.

In 1971, total fish landings were 98.0 million pounds with a value of $4.5 million. The leading species in volume were ocean perch (47.5% of total fish volume) sea herring (29.2%) and whiting (10.1%). In value the important species were ocean perch (51.1%) of total fish value) sea herring (15.3%) and whiting (10.6%). Total 1971 shellfish landings were 44.7 million pounds with a value of $26.6 million. The important species in volume were shrimp (41.1% of total shellfish volume) and American lobsters (39.4%). In value the major species were American lobster (65.8% of total shellfish value) and shrimp (14.3%).

In 1971 there were 486 fishermen working on vessel and 5,414 working regularly on boats and shore. In addition where were 5,908 casual fishermen.

In 1971, the value of processed fishery products was $54.8 million, which was a 28% increase over 1960. There were 242 wholesaling and processing plants with an average total employment of 3,229 persons, which was a decrease of 9.7% and 6.0% respectively over 1960 levels.

2. New Hampshire

New Hampshire has the smallest volume and value of fisheries landings of the New England states. In 1973, the volume landed was 1.4 million pounds with a value of $0.9 million. This represents a 16.7% increase in volume over 1960 levels and a 125% increase in value.

In 1971, fish landings in New Hampshire totalled 488,000 pounds with a value of $81,000. Total shellfish landings were 849,000 pounds, valued at $783,000.

The number of operating fishing units and fishermen is relatively small compared to the rest of the region. In 1971, there were 87 regular and 478 casual fishermen.

From 1960-1971, the value of processed fishing product in New Hampshire increased from $0.6 million to $17.9 million. During the same time period, however, the number of wholesaling and processing plants decreased from 17 to 13, while the average total employment in these plants increased from 99 to 358.

3. Massachusetts

In 1973, the total volume of fisheries landings in Massachusetts was 269 million pounds with a value of $57.4 million. This represented a 44% decrease in volume and a 59.9% increase in value over 1960.

In 1971, fish landings totalled 253.0 million pounds with a value of $28.3 million. The major species in volume were flounders (27.2%), cod (18.4%), and sea herring (17.1%). In value the leading species were flounders (40.6%), cod (20.1%) and haddock (18.7%). Shellfish landings in 1971 totalled 23.6 million pounds with a value of $20.0 million. The major species in volume were American lobster (25.8%), shrimp (25.4%) and scallops (25.4%). In value the important shellfish species were scallops (46.5%) and American lobsters (34.5%).

In 1971 there were 2,349 fishermen employed on vessels and 1,386 employed regularly on boats and shore. In addition there were 4,231 casual fishermen.

The value of processed fishery product in 1971 was $173.2 million. This was a 147% increase over the 1960 levels. There was a decline of 10%, to 212, in the number of wholesaling and processing plants. The average total employment in these plants was 4,777, a declin of about 2% over 1960 levels.

4. Rhode Island

In 1971, fisheries landings in Rhode Island totalled 105 million pounds with a value of $15.1 million. This represented a 51% increase in volume and a 297% increase in value over 1960 levels.

The total volume of fish landed in 1971 was 77.0 million pounds with a value of $5.1 million. The primary species in volume were menhaden (24.9%) and flounders (24.7%). The important species in value were flounders which made up 51% of the total value of fish landings. Shellfish landings in 1971 totalled 9.1 million pounds and were valued at $7.4 million. The primary species in volume were American lobsters (59.3%) and clams (30.8%). In value, American lobsters represented 81% of the total value of shellfish landings.

In 1971, there were 696 fishermen working regularly on vessels and 390 on boats and shore. There were an additional 928 casual fishermen.

The value of processed fishery product in 1971 was $5.3 million, a 104% increase over 1960. There were 32 wholesale and processing plants with an average total of 254 employees.

5. Connecticut

Total 1973 fisheries landings in Connecticut were 4.8 million pounds with a value of $1.3 million. This was a 25% decrease in volume and a 8% increase in value over 1960 levels. In 1971, total fish landings were 5.0 million pounds and were valued at $498,000. The volume of shellfish landings was 1.7 million pounds and the value was $1.2 million. Flounders were the most important fish species landed and American lobsters were the most important shellfish.

In 1971, there were 63 fishermen working on vessels, and 188 on boats and shore. There were also 550 casual fisherman.

In 1971 the value of processed fishery product was $254,000, down 73% from 1960. There were 8 wholesaling and processing plants in 1971, which employed an average total of 34 workers.

6. New York

The total fisheries landings for New York in 1973 were 36.6 million pounds with a value of $22.0 million. This level represented a decrease in volume of 71% and an increase of 150% in value over 1960 levels.

Total fish landings in 1971 were 20.2 million pounds with a value of $2.6 million. The major species in volume were flounder (50.0%) and scup or porgy (6.4%). In value the important species were flounder (36.4%) scup or porgy (15.5%). Shellfish landing in 1971 totalled 16.2 million pounds and were valued at $16.0 million. The important shellfish species in volume and value were clams with 76.5% and 70% respectively of total shellfish landings.

In 1971, there 552 fishermen working on vessels and 1,706 working regularly on boats and shore. In addition there were 2,953 casual fishermen.

The value of processed product in 1971, was $56.9 million, an increase of 80% over 1960. In 1971, there were 219 processing and wholesaling establishments with an average total employment of 2,332.

7. New Jersey

In 1973, a total volume of 209.8 million pounds of fishery landings with a value of $18.4 million was recorded for New Jersey.

[redacted]

For 1971, total fish landings were 80.5 million pounds with a value of $4.0 million. The major species in volume were menhaden (75.3%) and flounders (4.1%). In value the leading species were menhaden (25.0%) and flounder (19.3%). Total shellfish landings were 35.1 million pounds with a value of $8.1 million. The major species landed were crabs with 89% of shellfish volume and 69% of shellfish value.

In 1971, there were 1,083 fishermen working on vessels and 692 working regularly on boats and shore. There were also 905 casual fishermen.

The value of New Jersey's processed products in 1971 was $52.8 million. In that year there were 108 processing and wholesaling plants with an average total employment of 1,887.

8. Delaware

Total commercial fishery landings in Delaware for 1973 were 10.3 million pounds and were valued at $2.0 million.

Fish landings in 1971, were 432,000 pounds with a value of $92,000. Shellfish landings for that year were 9.2 million pounds with a value of $1.6 million. The main shellfish species landed were clams with 84.7% of shellfish volume and 68.7% of shellfish value.

In 1971, there were 92 fishermen working on vessels and 101 working regulary on boats and shore. There were also 521 casual commercial fishermen.

The value of Delaware's processed fish products in 1971 was $4.7 million which came from 16 processing and wholesaling plants. The average total employment for these plants was 269.

9. Maryland

Total fishery landings in 1973 for Maryland were 67.0 million pounds with a value of $20.7 million. These figures include both Atlantic Coast landings and Chesapeake Bay landings.

Fish landings in 1971 were 16.2 million pounds with a value of $1.7 million. The major fish species in volume were menhaden (36.4%), alewives (17.3%) and striped bass (16.7%). Total shellfish landings were 58.9 million pounds with a value of $17.9 million. The important species in volume were crabs (46.9%), oysters (29.0%) and clams (23.9%). The leading species in value were oysters (58.7%), clams (23.5%) and crabs (17.9%).

In 1971, there were 1,527 fishermen working on vessels and 4,474 working regularly on boats and shore. There were an additional 7,927 casual fishermen.

The value of processed products in 1971 was $68.1 million. There were 207 processing and wholesaling establishments with an average total employment of 3,735.

10. Virginia

Total fishery landings in Virginia for 1973 were 631.4 million pounds and were valued at $39.4 million. These figures include landings in the Atlantic and Chesapeake Bay regions.

In 1971, fish landings totalled 427.1 million pounds with a value of $9.3 million. The dominant species was menhaden with 92.3% of volume and 68.8% of the value of total fish landings. Total shellfish landings were 58.9 million pounds with a value of $17.9 million. The leading species in volume were crabs (75.0%) and oysters (13.0%). In value the major shellfish species were oysters (44%), and crabs (32%).

In 1971, there were 2,627 fishermen working on vessels and 1,370 working regularly on boats and shore. There were an additional 951 casual fisherman.

The value of processed fish products in 1971 was $45.1 million. In that year there were 248 processing and wholesaling plants with an average total employment of 4,161.

11. North Carolina

Total fishery landings in North Carolina for 1973 were 137.9 million pounds with a value of $16.1 million.

Total fish landings for 1971 were 119.2 million pounds in volume and $4.4 million in value. The most important species in volume were menhaden (66.7%) and alewives (10.6%). The leading species in value were flounders (25%) and menhaden (25%). Total shellfish landings were 24.2 million pounds in volume and $6.8 million in value. The most important species in volume were crabs (59.9%) and shrimp (31.4%). The leading species in value were shrimp (70.6%) and crabs (16.2%).

In 1971 there were 1,725 fishermen working on vessels and 1,07 working regularly on boats and shore. In addition, there were 1,360 casual fishermen.

The value of processed fish products for 1971 was $12.5 million. There were a total of 174 processing and wholesaling plants with an average total employment of 1,400.

12. South Carolina

Total fishery landings in 1973 for South Carolina were 21.1 million pounds with a value of $11.3 million.

In 1971, total fish landings were 4.7 million pounds with a value of $536,000. In terms of volume the most important fish species were spot (26%), catfish and bullheads (19.2%) and alewives (15%). In value, the major species were catfish and bullheads (26.9%) and sea bass (24.6%).

Total shellfish landings in 1971 were 19.4 million pounds with a value of $7.6 million. In volume the major species were shrimp (55.1%) and crabs (38.7%). In value the major species was shrimp (84%).

In 1971 there were 795 fishermen employed on vessels and 240 on boats and shore. There were an additional 487 casual fishermen.

The value of processed fish products for South Carolina in 1971 was $10.8 million. There were 75 processing and wholesaling plants with an average total employment of 764.

13. Georgia

Total fishery landings in Georgia in 1973 were 17.2 million pounds with a value of $10.6 million.

In 1971 total fish landings were 974,000 pounds with a value of $260,000. The principal fish species landed was shad which accounted for 43% of fish volue and 51% of value. Total 1971 shellfish landings were 17.4 million pounds, with a value of $7.2 million. The major species in volume were shrimp (51.1%) and crabs (48.3%). The principal species in value was shrimp which accounted for 89.6% of shellfish landings value and 86.4% of total landings value.

In 1971, there were 885 fishermen employed on vessels and 211 on boats and shore. An additional 453 casual fishermen were recorded.

The value of processed fish products in 1971 was $36.6 million. In that year there were 51 processing and wholesaling plants with an average total employment of 1,814.

14. Florida, East Coast [1]

Figures are not currently available for 1973 fishery landings in the Florida East Coast. In 1971, the landings for this area totalled 72.0 million pounds with a value of $14.8 million.

Total fish landings were 54.7 million pounds with a value of $7.2 million. The leading species in volume were menhaden (36.2%), and catfish and bullheads (29.8%). In value the principal species were catfish and bullheads (47.2%) and king mackerel (11.4%).

Total shellfish landings in 1971 were 17.3 million pounds and were valued at $7.7 million. The leading species in volume were crabs (53.2%), saltwater shrimp (22.9%) and spiny lobsters (19.6%). The major species in value were saltwater shrimp (42.9%) and spiny lobsters (37.7%).

In 1971, there were 1,159 fishermen working on vessels and 1,288 working regularly on boats and on shore. In addition there 502 casual fishermen.

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[1] The East Coast of Florida includes the coastal counties from Nassau to Dade.

The value of processed fish products for the east coast of Florida in 1971, was $38.3 million. There were 143 processing and wholesaling plants with an average total employment of 1,518.

(5) Oil and Gas Resources

The following estimates of oil and gas resources are provided by U.S. Geological Survey. USGS emphasizes that estimates are speculative; only the maximum credible expectations are shown.

TABLE 42. Estimates of undiscovered recoverable resources, 0-200 meters water depth. 1/

(Oil in billions of barrels and includes natural gas liquids)

(Gas in trillions of cubic feet)

Area	Estimated undiscovered recoverable resources: Oil	Gas
1. North Atlantic	0-10	0-50
2. Middle Atlantic	0-10	0-50
3. South Atlantic	0-10	0-50

TABLE 43. Estimate of undiscovered recoverable resources in coastal State waters. 1/

(Oil in billions of barrels and includes natural gas liquids)
(Gas in trillions of cubic feet)

Area	Estimated undiscovered recoverable resources: Oil	Gas
1. North Atlantic	0-2	0-5
2. Middle Atlantic	0-2	0-5
3. South Atlantic	0-2	0-5

1/ On March 26, 1974, the U.S. Geological Survey released estimates of the undiscovered recoverable oil and gas resources for broad areas of the OCS. Those estimates were based on statistical parameters of oil occurrences that apply only to broad geographic areas. It is entirely inappropriate to apply the same parameters to small, specific areas. The resource figures in the above table represent a general estimate, based on the above referenced table, of minimum and maximum volumes of oil and gas that might be recovered from the various OCS areas. It is statistically unsound to add the maxima and minima for an expectable range of resources for any larger area.

(6) Military Uses

There is extensive military use of the U.S. coastal shore areas. It is difficult to generalize about the varied military uses of these areas. Prior to granting leases in any coastal area the Department of Defense will designate the zones within the nominated area which are used for security, defense warning, or other military purposes. Negotiations with DOD and DOI will then follow.

(7) Historical and Projected Economic Growth North Atlantic - Middle Atlantic ("Northeast")

The information presented in this section is drawn in part from Chapter 12 of the Coastal and Offshore Environmental Inventory: Cape Hatteras to Nantucket Shoals, Complement Volume, Marine Publication No. 3, University of Rhode Island. The data has been revised using the latest OBERS data from the Bureau of Economic Analysis, U. S. Department of Commerce.

Economic activity in the Northeast Region is a dominant force in the national economy by nearly every measure, even though it has been growing more slowly than the nation as a whole. About 24 percent of all workers in the United States in 1970 worked in the Northeast Coastal BEA Economic Areas, and these residents of the area received 26 percent of the total personal income generated in the U.S. that year.

Table 44. Population, Employment, and Income, Regions and U.S., 1970

		(Northeast)		
	Total U.S.	N. Atlantic	Mid-Atlantic	S. Atlantic
Total Population	203,857,864	10,394,541	35,786,629	5,713,391
% of U.S.	----	5.1	17.6	2.8
Total Employment	79,306,527	4,293,184	14,536,763	2,189,312
% of U.S.	----	5.4	18.3	2.8
Total Personal Income	$708,583,931	$38,606,566	$144,889,903	$18,320,765
% of U.S.	----	5.4	20.4	2.6

Total personnal income in thousands of 1967 dollars.
Source: 1972-E OBERS BEA Economic Areas.

The most important economic activities in the Northeast are manufacturing, Federal Goverment, and the finance and service industries. In contrast extractive industries (mining, agriculture, forestry, and fisheries) play a relatively small role in the regional economy. The relative importance of population-related activities such as trade, State and local government, transportation, and construction is about the same in the Northeast as in the nation as a whole.

The following table shows earnings data for industries and their relative regional importance for the Atlantic Regions in 1970.

Table 45. Total Earnings by Selected Industries, 1970
(In thousands of 1967 dollars)

Industry	Total US	Northeast		S. Atlantic
		N. Atlantic	Mid-Atlantic	
otal Earnings	562,311,127	29,886,297	114,606,914	13,945,668
griculture, Forestry and Fisheries	19,640,721	293,967	1,284,168	633,292
% of Regional Total	3.5	1.0	1.1	4.5
Mining	5,647,503	20,949	161,457	31,917
% of Regional Total	1.0	0.1	.1	.2
Contract Construction	34,457,902	1,985,637	6,422,435	1,185,194
% of Regional Total	6.1	6.6	5.6	8.5
Manufacturing	156,291,100	9,428,230	28,260,449	2,206,572
% of Regional Total	27.8	31.5	24.7	15.8
Trans., Comm., and Public Utilities	39,925,053	1,756,760	8,753,714	1,184,363
% of Regional Total	7.1	5.9	7.6	8.5
Wholesale & Retail Trade	93,080,363	4,844,406	18,934,165	2,578,110
% of Regional Total	16.6	16.2	16.5	18.5

Table 45, cont.

Industry	Total US	Northeast		S. Atlanti
		N. Atlantic	Mid-Atlantic	
Finance, Insurance, Real Estate	28,880,241	1,827,850	8,379,860	831,08
% of Regional Total	5.1	6.1	7.3	6.0
Services	85,077,671	5,123,781	20,222,485	2,492,84
% of Regional Total	15.1	17.1	17.6	17.9
Government	99,310,475	4,550,157	22,562,234	2,802,31
% of Regional Total	17.6	15.2	19.7	20.1
	* 99.9	* 99.7	* 100.2	* 100.0

* Percents MAY NOT TOTAL 100 due to rounding.

Within the principal cities of the densely populated coastal belt, there has been a marked shift from blue-colar factory work to white-collar office employment. The inland areas are distinguished by the relatively greater importance of manufacturing in their economic base. The outlying areas have a relatively greater portion of land devoted to forests, parks and open spaces, agriculture, and mining.

ne Northeast is presently growing at a slower rate than it did n the previous two decades as measured by population and employent. As an older, more mature region with a homogeneous industrial ix, its original leading position is being gradually eroded by other egions entering periods of substantive growth.

he University of Rhode Island Report assessed the future general utlook for the Northeast:

> "While employment in the NAR [Northeast] is expected to grow at a rate commensurate with population, it will exhibit a continuing shift in composition--fewer production jobs in the manufacturing sector and more white collar and service jobs in office buildings. The distribution of new employment growth among belts in the region is expected to follow the pattern of population change, although manufacturing activity is likely to continue its shift from central cities to suburbs, reflecting the need for greater amounts of less expensive land, the continued elaboration of the highway network and a decreasing dependence on the coastal railroads as a transportation system. Finally, agriculture, forestry, fishing, and mining are projected to decrease in relative (and, in some cases absolute) importance as land values are pushed upward by the spread of urbanization and industrialization. However, an element of uncertainty exists here: the crisis in power generation and the development of coal gasification techniques, for instance, could introduce new vigor into the coal extraction industry, or the advent of controlled thermonuclear fusion could render it obsolete. Then, too, there are the untapped mineral reserves of the continental shelf, ... whose exploitation depends on the political resolution of opposing pressures of economics and environmental protection."

South Atlantic

This section is primarily based on a study by Planners Incorporated for the Bureau of Land Managemet.

The coastal areas of the South Atlantic from Cape Canaveral to Cape Hatteras constitute a generally depressed area with a major need for economic development and new employment opportunities. This region accounted for 2.8 percent of the U.S. population and employment but only 2.6 percent of the total personal income.

Per capita income was below the U.S. average in this region and less than three-fourths of U. S. per capita income in 1970. The percentage of all persons with families or single households with incomes below the poverty level was unusually high - 16 of the 30 counties of the South Atlantic region exceeded 25% (versus 13% for the U.S. as a whole) and 7 exceeded 30%. The poverty rates were high and per capita income was low in the rural areas and in areas of low economic growth. Poverty was exceptionally high for non-whites, and there is a close correlation between low income, depressed counties and the percentage of non-white persons living in the county. Earnings levels are low for minorities and females, and opportunities are especially limited for both. Aggregate income growth, the best indicator of economic development, was however growing more rapidly than the U. S. average in most counties. Thus a catching-up process has been occurring. Since 1967, annual income growth has been 2% or more above the U.S. average in the Wilmington SMSA, the Melbourne Titusville-Cocoa SMSA and in five individual counties. Per capita incomes have been rising as a percent of U. S. per capita income in all but two counties, as a result of rapid economic growth or outmigration.

Three-fourths of the population is concentrated in six Standard Metropolitan Statistical Areas: Jacksonville (580,000), Charleston (300,000), Melbourne-Titusville-Cocoa (230,000), Savannah (190,000), Daytona Beach (170,000), and Wilmington (110,000).

At a growth rate of 1.0% per year, the population of the thirty county coastal zone will reach 2,800,000 by the year 2000.

Farm income relative to U.S. farm income is declining with time, in large part due to poor soils. Farm employment is falling by 7% annually. Farm dependence is now high only in six counties.

Employment in forestry is not large, despite large acreages of forest, exceeding 300 workers only in one county, Charlston (South Carolina).

The annual fish catch value is about 100 million dollars in the South Atlantic. Mining operations for construction materials are scatered throughout the area, with large operations only in Beaufort

(North Carolina) in phosphate rock. With this exception, mining values are negligible as a percent of total incomes in each county.

The five major manufacturing centers, in order of importance, are the Jacksonville SMSA, the Brevard SMSA, the Savannah SMSA, the Charleston SMSA and the Wilmington SMSA. The dominance of manufacturing as compared with the U.S. average is highest in the Wilmington SMSA, and in Glynn, Georgetown, Beaufort (S.C.), and Colleton. The annual growth rate of manufacturing income exceeded the U.S. average by more than 1% annually in all of the counties listed above except Brevard, where it fell sharply, and in Savannah. These areas with the exceptions listed are the industrial growth centers of the area.

Since 1966, Wilmington has clearly been the fastest growing industrial growth center in the 30-county region. The largest and fastest growing chemical and petrochemical producer is the Wilmington SMSA, with Savannah second, Glynn third, Jacksonville fourth, and Charleston fifth. Paper and pulp production is widely distributed throughout the coastal counties. Fish processing is concentrated in a few counties. and the only moderate size ship and boatbuilding activities are in Jacksonville.

The high service areas are in coastal Florida, the Savannah SMSA, and the Wilmington SMSA. Government incomes, particularly military earnings are high in this region. Both public and private services, such as those for health, are extremely limited in low income and especially low-income rural counties.

Transportation, communications and utilities are above average in the SMSA's of Jacksonville, Savannah, Charleston, and Wilmington, and in Carteret. Contract construction is above average in most of the region's SMSA's.

Population in the South Atlantic region is projected to increase at a rate two and a half times that of the U. S. rate. Employment is projected to increase by almost three times that of the U.S. as a whole.

Table 46. Population, Employment, and Per Capita Income 1967
Historical and Projected, 1950-2000
(1972-E, OBERS Projections, Bureau of Economic Analysis,)

BEA	Economic Area	1950	1970	Percent 1950 to Change 1970	1980	1990	2000
001	Bangor, Maine						
	Population	312,934	323,969	3.5%	301,900	297,100	289,900
	Per Cap. Inc. .	1,427	2,663	86.7%	3,700	5,000	6,800
	Total Employ.	95,761	115,723	20.9%	119,400	119,700	122,500
002	Portland, Maine						
	Population	655,513	741,874	13.2%	744,900	774,400	796,100
	Per Cap. Inc.	1,763	3,016	771.1%	4,200	5,500	7,400
	Total Employ.	239,586	293,636	22.6	324,600	340,600	362,500
004	Boston, Mass.						
	Population	5,163,133	6,354,618	23.1%	7,030,800	7,739,800	8,411,800
	Per Cap. Inc.	2,226	3,775	69.6%	5,200	6,600	8,700
	Total Employ.	2,039,058	2,639,691	29.5	3,228,600	3,561,700	3,975,800
005	Hartford, Conn.						
	Population	2,084,855	2,974,080	42.7%	3,240,500	3,536,800	3,803,000
	Per Cap. Inc.	2,461	3,874	57.4%	5,300	6,700	8,900
	Total Employ.	859,924	1,244,134	44.7%	1,487,300	1,623,700	1,793,500
014	New York, N. Y.						
	Population	14,214,921	18,308,349	28.8%	19,782,900	21,711,500	23,511,300
	Per Cap. Inc.	2,743	4,489	63.7%	6,000	7,600	9,800
	Total Employ.	5,836,989	7,409,705	26.9%	8,953,600	9,914,300	11,122,100

BEA	Economic Area	1950	1970	Percent Change 1950 to 1970	1980	1990	2000
015	Philidelphia, Pa.-N.J.						
	Population	5,517,385	7,330,792	32.9%	8,025,400	8,653,700	9,188,300
	Per Cap. Inc	2,365	3,720	57.3%	5,000	6,500	8,500
	Total Employ.	2,207,384	2,931,657	32.8%	3,523,500	3,818,400	4,191,300
017	Baltimore, Md.						
	Population	1,935,904	2,679,935	38.4%	2,822,900	3,062,700	3,234,400
	Per Cap. Inc.	2,191	3,570	62.9%	4,800	6,200	8,200
	Total Employ.	774,807	1,087,132	40.3%	1,252,600	1,362,800	1,482,800
018	Wash.,D.C.-Md.-Va.						
	Population	1,661,277	3,095,493	86.3%	3,755,200	4,729,400	5,592,300
	Per Cap. Inc.	2,741	4,293	56.6%	5,600	7,200	9,300
	Total Employ.	738,119	1,358,192	84.0%	1,797,900	2,254,400	2,717,800
021	Richmond, Va.						
	Population	783,604	1,010,310	28.9%	1,162,500	1,311,400	1,423,100
	Per Cap. Inc.	1,694	3,318	95.8%	4,500	5,800	7,700
	Total Employ.	305,945	412,071	34.7%	515,600	584,000	653,100
022	Norfolk-Portsmouth, Va.						
	Population	838,391	1,234,090	47.2%	1,224,400	1,325,700	1,386,600
	Per Cap. Inc.	1,802	2,972	64.9%	4,000	5,200	7,000
	Total Employ.	342,303	503,558	47.1%	540,900	585,400	630,500
023	Raleigh, N. C.						
	Population	1,353,249	1,644,750	21.5%	1,788,100	2,009,200	2,159,900
	Per Cap. Inc.	1,270	2,610	105.5%	3,600	4,700	6,500
	Total Employ.	477,602	636,600	33.3%	762,500	861,700	958,800

Table 46, cont.

BEA	Economic Area	1950	1970	Percent Change 1950 to 1970	1980	1990	2000
024	Wilmington, N.C.						
	Population	374,066	482,902	29.1%	471,500	516,000	544,000
	Per Cap. Inc.	1,379	2,739	98.6%	3,700	4,900	6,700
	Total Employ.	136,443	197,848	45.0%	207,500	277,500	247,100
030	Florence, S.C.						
	Population	396,402	401,586	1.3%	436,900	474,700	491,900
	Per Cap. Inc.	903	2,211	144.9%	3,100	4,200	5,900
	Total Employ.	135,777	144,261	6.3%	176,700	193,400	207,800
031	Charleston, S.C.						
	Population	290,415	431,673	48.6%	407,900	434,100	447,600
	Per Cap. Inc.	1,361	2,725	100.2%	3,800	5,000	6,700
	Total Employ.	102,128	166,803	63.3%	173,400	184,800	196,800
033	Savannah, Ga.						
	Population	367,470	418,897	14.0%	423,400	445,700	452,000
	Per Cap. Inc	1,232	2,559	107.7%	3,500	4,700	6,400
	Total Employ.	129,464	155,903	20.4%	172,400	182,900	192,500
034	Jacksonville, Fla.						
	Population	670,629	1,057,007	57.6%	1,234,100	1,425,700	1,569,900
	Per Cap. Inc.	1,542	2,985	93.6%	4,100	5,300	7,100
	Total Employ.	246,838	407,999	65.3%	520,100	601,800	683,800
035	Orlanda, Fla.						
	Population	306,375	951,437	210.6%	1,209,200	1,440,000	1,622,300
	Per Cap. Inc.	1,751	3,111	77.7%	4,300	5,600	7,500
	Total Employ.	111,945	351,029	213.6%	490,800	577,000	662,600

BEA	Economic Area	1950	1970	Percent Change 1950 to 1970	1980	1990	1980
036	Miami, Fla.						
	Population	786,050	2,452,791	212.0%	3,408,400	4,408,000	5,300,600
	Per Cap. Inc.	2,162	3,698	71.0%	5,000	6,700	8,100
	Total Employ.	318,800	963,317	202.2%	1,377,400	1,711,300	2,032,500

Table 47.

Regional Population and Employment
(1972-E, OBERS, Bureau of Economic Analysis)

Region	1950	1970	Percent Change 1950 to 1970	1990	Percent Change 1970 to 1990
North Atlantic BEA Areas 001, 002, 004, 005					
Population	8,216,435	10,394,541	26.5	12,348,100	18.8
Employment	3,234,329	4,293,184	32.7	5,645,700	31.5
Middle Atlantic BEA Areas 014, 015, 017, 018, 021, 022, 023, 024					
Population	26,678,797	35,786,629	34.1	43,319,600	21.0
Employment	10,819,592	14,536,763	34.4	19,658,500	35.2
South Atlantic BEA Areas o30, 031, 033, 034, 035, 036					
Population	2,817,341	5,713,391	102.8	8,628,200	51.0
Employment	1,044,950	2,189,312	109.5	4,343,300	98.4
United States					
Population	151,236,648	203,857,864	34.8	246,039,000	20.7
Employment	57,474,912	79,306,527	38.0	106,388,000	34.1

d. Existing Environmental Quality Problems in Coastal Zone

(1) Water Quality

Major centers of high population concentrations occur along the Atlantic coastline. Embayments along the coast receive large quantities of industrial, agricultural, and municipal wastes. Several factors impact upon the water quality as a result of these effluents. Flushing times of embayments and rivers influence the maximum acceptable pollutant loading in that pollutant levels are cumulative to varying degrees.

Seasonal rates of freshwater funoff are usually higher in winter and spring than in summer and fall. Water quality would thus be further degraded during these low-flow seasons if the quantities of pollutants added remained the same throughout the year. The types and quantities of industrial effluents are significant. Heavy metals are toxic and have extended residence times in the estuary; they are subject to resuspension when the substrate is disturbed. The degree of sewage treatment is also important in the effluent's effect on dissolved oxygen and other water quality parameters. The types of pesticides being used in the watershed have particular significance in governing water quality. Long-lived pesticides such as DDT and its metabolic derivatives DDD and DDE have proven extremely harmful to organisms associated with embayments and rivers. More recently developed pesticides such as Sevin (a carbamate) are biodegraded over short periods of time and do not pose as significant a problem as do longer-lived pesticides.

Thus, water quality varies with the type and amount of pollutants added to a specific estuary, and can vary between estuaries which are in the same region. Florida's Biscayne Bay receives significant levels of sewage. Periodic plankton blooms of the dinoflagellate _Gymmodium_ (red tide organisms) normally occur under present pollutant levels. These blooms have been responsible for fish kills and effects ranging from general nuisance to public health hazards.

An extensive "_Estuarine Pesticide Monitoring Program_" (conducted by the Fish and Wildlife Service) is underway along the Atlantic coast. The objective of this effort is to monitor pesticide residue levels in fishes along the coast. DDT levels, which historically have caused significant problems in commercial fisheries, appear to be declining due to the partial ban on its agricultural use. The concentrations of all pesticides in tissues indicate that concentrations in the water were in the range of tens of parts per trillion along the southeastern region. DDT has been proven to have been concentrated in successive trophic levels, causing concern for health at the commercial fisheries level.

The Saint Johns river system, which constitutes the major Florida estuary along the Atlantic coastline is apparently not heavily polluted at this time. Detectable levels of heavy metals were found in this estuary however (VIMS, 1974).

The rivers and estuaries of Georgia and South Carolina normally do not reach oxygen saturation during the annual cycle. The addition of pollutants which would require oxygen during eutrophication (nutrient enrichment) (as do most pollutants) would impose severe stresses to the biota residing therein. Stickney and Miller (1973) reported oxygen concentrations below 2 mg/l, a stressful level in the Savannah River. This low oxygen concentration is primarily due to the injection of sewage and industrial pollution. The St. Marys and Amelia Rivers and Cumberland Sound are stressed by additions of sufficient pollutants to cause a dissolved oxygen level below 2.0 mg/l. Charleston Harbor has shown high nutrient levels as a result of pollution (VIMS, 1974).

Detectable levels of pesticides were reported (Mahood, et al., 1970) in blue crabs taken from the entire Florida-North Carolina region Aldrin, BHC, dieldrin, DDT, DDE, DDD, ondrin, heptochlor epoxide, methoxychlor, Mirex, toxaphene, and chlordane were all present in these samples. The "Outer Banks" system and its associated embayments (Pamlico, Bogue, Arbemarle Sounds, etc.) have not been heavily influenced by man. The area remains relatively sparsely settled and no significant heavy industry influences the coastal water quality.

The Chesapeake Bay system is heavily loaded with pollutants, but fortunately is capable of rapid assimilation. This geographical area is experiencing rapid population growth which is exceeding the capability of sewage treatment plants. The major concern for this embayment is more adequate effluent treatment. Currently 42,000 acres of shellfish beds are closed to commercial fishermen because of pollution loading. The James River is an extreme example of the effects of high pollutant levels. The City of Richmond, Virginia dumped 33% of its sewage (population 500,000 in 1967) into the river untreated. Hopewell and Hampton Road also added to the pollutant loading. Heavy plankton blooms are common in this river. Both nitrogen and phosphorus are normally present in excess of the ability of phytoplankton to utilize them in winter. Extensive closing of potentially productive shellfish beds have occurred in the Hampton Road area because of bacterial levels. The overall effect of these high nutrient values has been to alter the food web in favor of species more able to survive the polluted conditions. Red tides are common in the lower Chesapeake Bay and reach the nuisance level. Extensive fish kills because of these plankton blooms, however are not common (Brehmer, 1967).

Water pollution in Delaware Bay below Trenton is particularly severe. Municipal and industrial effluents are predicted to double between 1964-1975, and increase 5 1/2 times by 2010. Water completely depleted of oxygen occurs in locations near point source effluents. Concentrations of coliform bacteria are high and the pH of the water is significantly lowered by industrial acid dumping. Floating materials including oil scums and untreated sewage are visible along stretches of the bay.

The coastal waters of the northern New Jersey are severely degraded by pollution. The majority of waters in this region are closed to swimming and are classified as unsuitable for recreational boating and fishing. Diverse pollutants including phenols, oils, trace metals, and waste heat can normally be found in waters in this region. The coastal and estuarine waters in the New York metropolitan regions are heavily used for disposal of solid wastes, liquid sanitary wastes, and waste heat. Ninety-seven non-industrial and 42 industrial sources of pollution were identified in 1960 (URI, 1974). The coastal waters offshore have been used as dumping grounds for an estimated total of 9.6 million tons of solid wastes in 1968. This solid waste was a combination primarily of dredge spoils, fly ash, incineration residue, sewage sludge, and construction rubble. Heat released from several large thermoelectric generating plants also is injected into the system.

The coastal waters of New York and New Jersey receive tremendous amounts of domestic wastes. Ryther and Dunston (1971) reported that approximately 4 billion kiloliters of domestic waste entered the New York Bight area daily.

Moriches Bay has previously been described in this paper. Shellfish beds have been closed because of high coliform bacteria count resulting from untreated runoff from duck farms. High plankton populations and reduction of fish populations have resulted.

Long Island Sound water quality varies considerably from area to area. Generally the water quality is more degraded in the western portion. Water quality is good from the Connecticut River eastward. The combined industrial effluent and sewage from the New York metropolitan area is responsible for the conditions in the western portion of the sound. Temporary shifts in water quality occur causing locally severe conditions. Thermal loading is predicted to be a problem in the future. Increased demand for cooling water for planned thermoelectric plants is primarily blamed for this predicted increase (URI, 1974).

The coastal waters off Massachusetts are polluted to levels which curtail the commercial shellfish industry. Recreational pursuits have been reduced and ground water is apparently being degraded by industrial wastes and sewage. Coastal sewage loading from commercial vessels and recreational boating is blamed for a significant input of untreated sewage. Population growth is presently exceeding the capabilities of local sewage treatment plants and the coastal situation is predicted to worsen (URI, 1974).

Pawtuxet Basin, Rhode Island, experiences low dissolved oxygen, high coliform counts, and high turbidity levels. Both sewage and industrial wastes are discharged into the river from 24 major discharge points (TRIGOM, 1974).

The coastal waters along Rhode Island are relatively free of pollution. Narragansett Bay receives a variety of municipal discharges including; industrial wastes, heated waters, stormwater runoff, and effluents from combined sewers. Oil pollution resulting primarily from oil transportation and refining in the bay is a problem. Areas of shellfish beds are closed following freshwater runoff.

Blackstone Basin in Massachusetts and Rhode Island receives large amounts of treated and untreated domestic sewage (TRIGOM, 1974). During dry seasons, almost all (90%) of the entire flow below Worcester is effluent from the Worcester sewage treatment plant.

Ten Mile River basin (Massachusetts and Rhode Island) receives inadequately treated waste water and industrial effluents. Heavy metal discharges and point sources of sewage further degrade water quality locally. Increased siltation due to extensive land alterations have caused severe local degradation.

New Bedford Harbor (Massachusetts) is moderately loaded with agricultural runoff and municipal sewage. Water quality in this area may improve with the recent completion of the sewage treatment plant at Fairhaven.

Boston Harbor receives wastes and sewage from the Mystic, Charles, Neponset and Weymouth-Fore Rivers. Combination sewers along these rivers cause high loading stresses during rainy periods. Oil pollution can be severe locally. Heavy oil transport traffic and storage facilities contribute to the oil hazard. Chronic hazards in the harbor have been recognized (TRIGOM, 1974).

The Neponset River (Massachusetts) is a critically polluted estuary with extensive marshlands. Urban runoffs, combined sewers, and paper mill effluents are primarily responsible for the high pollution loading in this embayment.

Charles River basin (Massachusetts) is adversely affected by municipal and industrial waste discharges. The river is closed to any water contact activities.

The Mystic Basin (Massachusetts) contains some of the region's most intensive industry. Urban runoff is high and, during periods of low flow, obnoxious odors emanate from the water. Bacterial counts are high, and no living benthic organisms have been found in black oozes which occur in the system (TRIGOM, 1974).

The waters in the Ipswich-North Shore Basin are rated substandard because of urban runoff, combined sewer flow, and untreated municipal waste.

The Piscataqua River suffers from the injection of industrial wastes and inadequately treated sewage. The major degradation to water quality in this river is due to point source pollution by several specific industries (TRIGOM, 1974).

The Presumpscot River in Maine, is polluted in its lower region by industrial and municipal effluents. At the river's mouth, obnoxious odors are common, and floating scum is commonly found.

The Androscoggin River is severely polluted along stretches of its length. Fish kills, floating bottom deposits, obnoxious odors and distinct color all appear in areas. Industrial influences are primarily responsible for these conditions.

The Kenebec River basin is the second most populated river in Maine. Untreated sewage and effluents from varied industries contribute to the degradation of water quality in the river. Large areas of 0.0 mg/l dissolved oxygen exist during summer.

Recognized point source pollutants from industries are the prime causes of poor water quality in the river.

Pulp and paper industrial loading is primarily responsible for the pollution stresses on the lower Penobscot River in Maine. Reduction of sulfite effluents from several major pulp plants have significantly improved the water quality along certain stretches of the river. Most small population areas along the river inject raw sewage with no treatment.

Thus major water quality problems presently exist along the Atlantic. Detailed information for each river must be kept up to date as the pollution loadings change with land modifications, increases in populations, industrial waste treatment, municipal sewage plant completions, and river runoff levels.

(2) Air Quality

Air quality is generally good along the Atlantic coastline. In the vicinity of cities and industrial complexes however, air quality can reach health hazard levels. The major factors affecting air quality are quality and quantities of pollutants emitted, distance from point sources, and meteorological conditions. Extended periods of thermal inversions reduce the vertical mixing in the air column. Pollutants which are emitted during these periods are trapped at lower altitudes and may build to hazardous concentrations. Figure   depicts predicted occurrences of heavy pollution based upon observed weather conditions. Table presents the present status of air quality control regions along the Atlantic coast.

Secondary standards (Table   ) for SO_2 have been waived for the duration of the energy shortages the region is now experiencing.

(3) Dredging

Major dredging efforts are underway along the Atlantic coastline. These activities are too numerous to describe within the scope of this document. The major goals of most of these activities are replenishment of beach sands and deepening and widening of navigable channels. Other less important objectives include land fill and recreational boat harbor maintenance. For a more expanded discussion of the impacts of these actions on water quality, refer to the section on impacts.

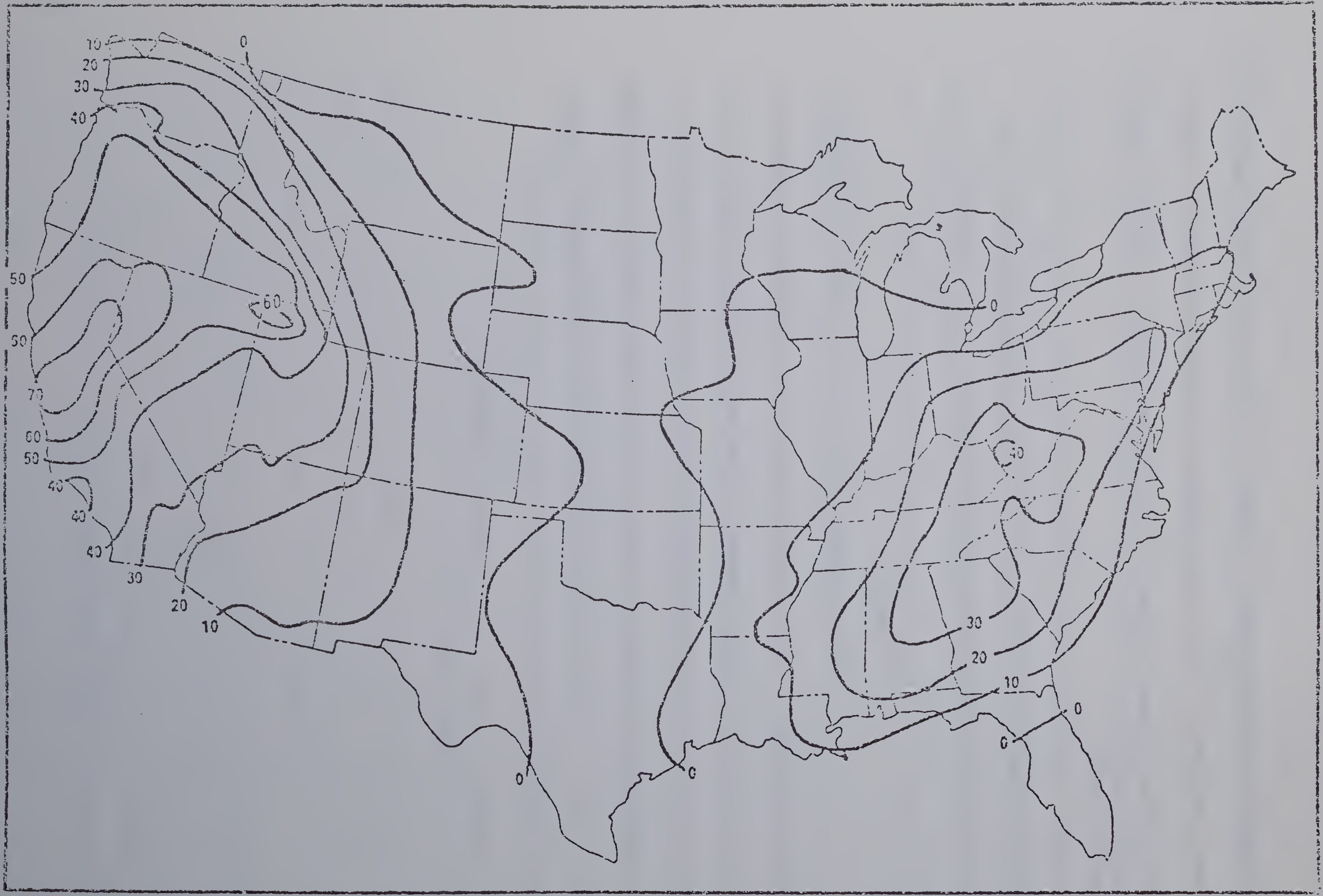

Figure 110. Isopleths of total number of forecast-days of high meteorological potential for air pollution in a 5-year period. Data are based on forecasts issued since the program began, August 1, 1960, and October 1, 1963 for eastern and western parts of the United States, respectively, through April 3, 1970. (After Holzworth, 1972).

TABLE 48.

NATIONAL AIR QUALITY STANDARDS

Parameter	Standard [a]	
	Primary	Secondary
Particulates		
Annual Geometric Mean	75 ug/m^3	60 ug/m^3
24-hour average	260 ug/m^3	150 ug/m^3
Sulfur Dioxide (SO_2)		
Annual Arithmetic Mean	80 ug/m^3	60 ug/m^3 [b]
	.03 ppm	.02 ppm[b]
24-hour average	365 ug/m^3	260 ug/m^3
	.14 ppm	.1 ppm[b]
3-hour average	na	1300 ug/m^3 [b]
Nitrogen Dioxide (NO_2)		
Annual Arithmetic Mean	100 ug/m^3	100 ug/m^3
Carbon Monoxide (CO)		
8-hour average	10 mg/m^3	10 mg/m^3
	9 ppm	9 ppm
1-hour average	40 mg/m^3	40 mg/m^3
	35 ppm	35 ppm
Hydrocarbons		
3-hour average	160 ug/m^3	160 ug/m^3
6-9 A.M. average	.24 ppm	.24 ppm
Photochemical Oxidants		
1-hour average	160 ug/m^3	160 ug/m^3
	.08 ppm	.08 ppm

[a] Standards quoted are maximum values. Primary standards are "health" related, secondary are "welfare" related. The standards, except for annual averages, may be exceeded only once per year per monitoring site. Annual averages may never be exceeded.

[b] Secondary standards for SO_2 have been temporarily revoked due to the "energy crisis" (personal communication, EPA, April, 1974 from TRIGOM, 1974)

SOURCE: The *Federal Register*, November, 1971.

TABLE 49.

A SAMPLE OF COASTAL AIR QUALITY CONTROL REGIONS BY CATEGORY FOR THREE TYPES OF POLLUTANTS

Air Quality Control Region	Category by Type of Pollutant		
	SO_2	NOx	HC
Connecticut:			
Hartford, New Haven, Springfield Interstate, AQCR No. 42	I	I	I
Eastern Connecticut Intrastate, AQCR No. 41	II	III	III
Delaware:			
Southern Delaware Intrastate, AQCR No. 46	III	III	III
Florida:			
Jacksonville, Brunswick Interstate, AQCR No. 49	I	II	III
Central Florida Intrastate, AQCR No. 48	II	III	III
Southeast Florida Intrastate, AQCR No. 50	II	III	I
New Jersey:			
New Jersey Intrastate (Ocean, Atlantic, Cumberland, and Cape May Counties), AQCR No. 150	III	I	III
South Carolina:			
Charleston Intrastate, AQCR No. 199	I	I	III
Savannah Beaufort Interstate, AQCR No. 58	I	I	III
Virginia:			
Hampton Roads Intrastate, AQCR No. 223	I	II	I
Northeastern Virginia Interstate, AQCR No. 225	I	III	I

Source: Unpublished EPA data.

* Category I: Air quality does not meet primary standards.
Category II: Air quality meets primary standards.
Category III: Air quality meets secondary standards.

B. Description of Nearshore and Coastal Zone Environment

1. Gulf of Mexico Region (and Sub-Areas)

a. Geology

The geology of the nearshore and coastal zone has been described in the discussion of the offshore environment (section II.A.2.a.). This was done to present a complete and continuous description. Unlike biological and some physical parameters, geologic structures are not commonly distinguished according to an arbitrary division based on water depth or proximity to the shoreline. Where specific geologic structures are unique to a nearshore area, they are noted as such.

b. The Biological Environment and Communities of the Coastal Zone

The area under consideration here is the band of coastal lands and waters from the tidal zone landward to the level of 20 feet above MSL (mean sea level), or roughly thirty miles inland and extending along the northern Gulf of Mexico from the southern end of Florida to the Rio Granade at the Texas-Mexico border. Also treated are the embayments and barrier islands.

The direct distance along this coastline is approximately 1600 miles; however, the circuitous route of coastline through the bays and estuaries is estimated to be at least 10 times this distance. The paramount feature of the Gulf coast is the Mississippi River Delta and its associated seven million or more acres of marsh and estuaries. The Mississippi watershed covers about one-third of the United States, and the resultant freshwater discharge is responsible for the major saltwater dilutions within the central Gulf coast region. The Mississippi contributes most of the nutrients to the estuaries of Louisiana - the most extensive in the Gulf - which supports the third largest shrimp production and the second largest oyster production in the United States (U.S. Dept. of Commerce, 1974).

East of the Mississippi Delta, the proportion of estuaries to the coastal zone diminishes and becomes more commonly characterized by high energy sand beaches. The wetlands which are present are extremely valuable in terms of biological productivity.

Along the northwest Gulf coast, the marshlands diminish rapidly into a narrow band along the coast, and are nearly absent in the semiarid regions of South Texas. A significant portion of the coastal zone, however, is composed of a vast system of bays and lagoons which are engendered for the most part by the extensive system of barrier islands.

(1) Salt Marsh

Most salt marshes exhibit distinct zonation by the most abundant plants. This zonation is controlled by a variety of factors including soil types, soil salinity, tide, elevation, drainage characteristics and pH. The extent of saline intrusion into the marsh depends to a large degree on the rate of percolation (movement through soils) of saltwater at high tide (Jackson, 1952), and the location of points of influx of freshwater from the mainland.

In the vicinity of the Mississippi Delta, the saline marsh is generally adjacent to the beach rim and may vary from 1 to 15 miles in width. The saline marsh merges with the broad band of brackish marsh which is further removed from the sea rim and vegetated by wire grass, coco, and three-cornered grass.

The comparatively small number of plant species of the saltmarsh limits the number of available niches in which organisms may live. Chabreck (1972) recorded only 17 plant species present in the coastal saltmarsh of Louisiana, with saltmarsh cordgrass (*Spartina alterniflora*) being the dominant species. However, with the inland marsh succession, habitat complexity increases significantly. The same author noted 93 plant species present in the fresh marsh.

While there may be small regional differences in composition within the saltmarshes of the Central Gulf, these data represent general composition.

The dominant plant, cordgrass, most densely distributed along the seaward side of the marsh. Of all marsh species, cordgrass is best able to endure the longest and deepest inundation by saltwater (Humm, 1973).

Blackrush, *Juncus roemerianus*, accounts for about 10% of the composition and is distributed throughout the saltmarsh on slightly higher ground than cordgrass.

Saltgrass, *Distichilis spicata*, is limited to a more inland location in the saltmarsh. This plant grows on slightly higher elevation than the peat deposits to which it contributes, and is inundated only in storm tides.

Batesgrass, *Batis maritima*, and wiregrass, *Spartina patens*, comprise small percentages of the Louisiana saltmarsh. Twelve remaining species account for less than 1% of total vegetation in the saltmarsh.

Since much marsh productivity goes to nourishing other ecosystems, the numbers of resident animals which depend on this ecosystem for their entire livelihood are also limited. Resident salt marsh species include primarily the furbearing muskrat, nutria, racoon and otter, wading birds and reptiles and amphibians. Because of the nutrient turnover these marshes provide, they also rate high in value for wintering waterfowl.

(2) Brackish Marsh

Brackish marshes are usually situated between the seaward salt marsh and landward intermediate and fresher marshes. In the Gulf of Mexico region, these brackish marshes are primarily located in southeastern Texas, southwestern Louisiana and along the west coast of Florida.

Salinities vary annually between an average low of 3.4 ppt to an average high of 16.7 ppt. Highest salinities occur in June, or in the drought periods (Palmisano, 1971).

Plant species diversity increases as one approaches the upland environment from the marsh. Forty species of plants (Chabreck, 1970) have been recorded in the brackish marsh. The dominant species wiregrass, Spartina patens, comprises 55% of the total vegetation. Saltgrass, Distichilis spicata, makes up 13.13% of the remaining 38 species. Only 5 other species have been recorded with coverage greater than 2-5%.

The coastal zone of the northern Gulf of Mexico provides some of the best, if not the "premier", waterfowl wintering habitat in North America (Gusey and Maturgo, 1973). Of this total area, the coastal marshes of Louisiana and the rice area of southwest Louisiana constitute the largest general waterfowl wintering area within the United States. However, not all of the coastal marsh zone is suitable for waterfowl. Since most waterfowl food plants are confined to fresh and brackish-water marshes, and to fresh water ponds throughout the area, waterfowl tend strongly to concentrate in these areas. There is little evidence that the more saline marshes are used by waterfowl to any extent. Throughout the coastal marsh area, food and water conditions are highly variable, and waterfowl concentrations shift frequently from one area to another. Consequently, waterfowl do not generally winter throughout the entire coastal marsh area, and may be totally absent from some areas throughout the winter.

Great fluctuations in Gulf coast waterfowl habitat characterize these marshes. Hurricanes, marsh fires, erosion, subsidence, silt deposition, animal populations, and human activities are but a few of the factors that cause constant change in the waterfowl habitat of coastal Louisiana. Levees and canals have had an adverse effect; nevertheless, the coastal marshes continue to demonstrate an exceptionally high carrying capacity by holding more than 2/3 of the total wintering population in the Mississippi Flyway. In 1968, the Mississippi Flyway contained more than 1/3 of the U. S. population of wintering waterfowl.

(3) Intermediate Marsh

Intermediate marshes extend further inland than brackish marshes. In the Gulf of Mexico coastal zone they are distributed predominantly in the southwestern region of Louisiana and southeastern Texas.

A more diverse vegetation occurs in the intermediate marsh than the brackish or saline marshes. Based on the data given by Chabreck (1970), fifty-four species of plants or 35% more than in the brackish zone occur in the intermediate marshes. The dominant wiregrass makes up a third of the vegetation. Roseau, *Phramites communis*, and bulltongue, *Sagittaria falcata*, form 6.63% and 6.47% of the vegetation, respectively.

The intermediate marsh is heavily colonized by mammalian fur bearers. Natural plant distribution has been significantly altered in much of the marsh because of the fur mammal management practices of man. Much of the marsh has been burned, or burned and sodded to provide stands of three-cornered grass and other muskrat foods.

(4) Freshwater Marsh

The only freshwater marsh in the area of interest is situated in the more central region of the Mississippi delta near the distributary passes. Major species of vegetation in this marsh are: roseau cane, Eurasian water milfoil, alligator weed, duck weed, water hyacinth, dogtooth grass, bulltongue, and pondweed (Stone, 1972).

(5) Mangrove Swamp

The three common mangroves in the order of their abundance are the red mangrove, the black mangrove, and the buttonwood, and their zonation landward is in that order. A fourth and less abundant species, the white mangrove, generally grows landward of the black mangrove. Their distribution is world-wide on tropical and subtropical shores of oceans and estuaries. However, their distribution in the Gulf states is limited principally to Florida, but small populations do exist on some of the barrier islands off the Louisiana coast.

Mangroves grow on peat, muck, marl, sand, or rock, and such environmental factors as killing frost and land elevation control their distribution. Their seedlings germinate while attached to the parent tree; seedlings detach and float in the sea, where they remain alive several months, allowing them to be carried long distances by currents.

As with salt marshes, mangrove stands serve as a transitional buffer zone between stretches of low-energy coastal waters and uplands. They afford greater protection from storms and hurricanes than broad salt marshes, not only against wave action and high water but also against winds. Mangroves are active land-builders as well as lowland protectors. Debris that accumulates in their tangle of prop roots is partly converted into peat upon which they grow.

Mangrove stands are a habitat for many species of marine algae that attach to their prop roots, along with a host of both sessile and freeliving invertebrates. A variety of birds are characteristic of mangroves, some of which produce rookeries on the islands, but very few animals are restricted to mangrove stands.

(6) Barrier Islands

Several groups of barrier islands front the coastal states of the Gulf of Mexico. Many offer environments distinct from the other island groups. The following narrative describes representative islands for different regions of the Gulf.

The Texas coastal area is fronted by a 300 mile long chain of barrier islands and peninsulas. The most prominent of these in terms of length is Padre Island which extends from Brownsville to Corpus Christi. The vegetative communities on this island differ somewhat from those on the mainland principally in density and woody species. Padre Island is also a rather severe environment for mammals, reptiles and amphibians since high summer temperatures, strong winds and occasional droughts are not infrequent. Nevertheless, viable faunal communities consisting of birds, mammals, reptiles and amphibians do thrive in the area.

The island today is a grassland with seacoast bluestem and seashore dropseed dominating the foredunes with sea oats and railroad vine occupying the dune surfaces. An assortment of other grasses and forbs are also intermixed with the above species. Higginbotham (1972) estimated that about 61 per cent of the island was low coastal sands with seacoast bluestem and gulfdune paspalum being the dominant vegetation. Wildlife species associated with the island vegetative type consist principally of xeric (dry environment) species of small mammals and reptiles. Predators (coyotes, badgers, etc.) are also normal participants in the community.

Salt marshes occur sparsely on the landward side of the island. These occur mainly as poorly drained shallow depressions at or slightly above sea level. Vegetation is represented by species of cordgrasses, flatsedges and rushes with several species of aquatic forbs intermixed. Wildlife use consists of winter utilization by waterfowl, seasonal occurences of shore and wading birds and aquatically oriented reptiles.

The salty sands type of Padre Island is rather sparsely vegetated. Basically, the dominant plants are the same as those occupying the

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salt marsh but in lower abundance. Various shore birds are the only wildlife that utilize the area to any extent, primarily searching for food.

Vegetation in the shoregrass flats consist almost entirely of dense stands of shoregrass with a few forbs intermixed.

Terrestically oriented wildlife associated directly with the beach environment of Padre Island is almost totally dominated by several species of shore and wading birds. The beach provides the bulk of the food supply for these birds as food organisms are washed ashore by wave and tidal action. Several predacious birds also utilize this environment, searching for food in the shallow waters adjacent to the beach.

Marine turtles are totally dependent on beach habitat for nesting activities. Three of the sea turtles (leatherback, hawksbill and Ridley) in the Gulf of Mexico are classified as endangered. However, their occurrence on Padre Island is incidental and recent nesting attempts have not been verified.

There are three prominent groups of barrier islands along the Louisiana coast: (1) the Chandeleur Islands, (2) Grand Isle and Grande Terre Isle, and (3) Isles Derniere and the Timbaliere Islands.

The flora of these islands is a microcosm of the Louisiana marshlands. Beach and dunes, fresh and salt marsh, sand flats and interior plant association are all represented.

The Chandeleur Islands form a chain nearly 50 miles long, but less than 2 miles wide, estending from the Mississippi Sound in the north to Breton Sound in the south. The Gulf coast of the island chain is beach and dune backed by interior shrub and sand flats. Fresh, brackish and salt marsh follow in sequence as the Chandeleur Sound is approached. Seagrasses cover much submerged area on the landward shore of the island.

The Grand Isle chain has a complex vegetational distribution pattern, probably due to its proximity to the mainland. Salt marsh covers the northern part of Grand Terre Island along Barataria Bay. The southern corner of Grand Isle is beach, followed by dune with meadow and forest spread through the center of the islands.

The Derniere-Timbaliers are largely saltmarsh on their landward sides with a wide beach along the Gulf. The dunes are covered with saltmeadow cordgrass *Spartina patens*, saltgrass *Distichilis spicata*, threesquare *Scirpus americanus*, two morning glories, sea ox-eye, love grass, sea pine, lippia, croton and minor species.

Valentine (1970) reported on the fauna of Isle Dernieres. Most important use was by herons and egrets of which over 3500 nests were discovered on one island of the chain. There was also 1700 nests of gulls and terns estimated on one of the small islands. The mud and sand flats provide habitat for thousands of shorebirds. Because of frequent tidal flooding by severe storms, the small mammal population is very low. A few fox, raccoon, muskrat, rabbits, nutria and cotton rats are probable residents.

(7) Seagrasses

Seagrasses consist of species of flowering plants that grow completely submerged (some are tidally emergent) in brackish to saline waters. They are limited to waters where sunlight penetration permits photosynthesis, such as are found in the shallow waters of bays and around islands in areas of low turbidity.

Marine grass beds support one of the highest biomass densities in the marine environment, for they not only provide a valuable food source for migratory waterfowl and shorebirds, but are also prime nursery grounds for shrimp, crabs, and fishes of all types. While few animals feed on the grasses, many feed on organisms which attach to or live on them, viz., snails and mussels.

Seagrass communities are fragile ecosystems which advance and decline readily in response to minor changes in water quality, turbidity, or sediment loads and are vunerable to storm damage. They are therefore difficult to quantify and chart with accuracy on a regional basis (U. S. Army Corps of Engineers, 1973).

The Mississippi River interrupts an otherwise continuous band of seagrasses which extend along the Gulf Coast from Florida to Texas. The turbid fresh water of the river adversely affects inshore seagrass beds as far southwest as Galveston, Texas (Humm, 1973). Of the 647 plant species recorded in the Gulf of Mexico, 329 occur from the shore to 10 m depth (Earle, 1972). The most common species include turtlegrass, manateegrass, shoalgrass, and widgeongrass. The latter species is found in the less saline waters of the coastal inlets and bays.

Turtlegrass, Thalassia testudinum, is the most abundant species in the eastern Gulf where it may account for 60 to 75% of all seagrasses in terms of bottom cover (Humm, 1973). It attains its most extensive development over hundreds of square miles of calcareous sand bottom overlying limestone between Tampa Bay and Cape San Blas, Florida. In the central and western regions of the northern Gulf coast it occurs in limited stands in the more saline areas of bays and along the backsides of barrier islands. Associated with these turtle grass beds are numerous other species of sea grass and benthic algae.

Shoalgrass, Diplanthera wrightii, occupies the most extensive geographic range of all seagrasses in the Gulf, and is the most tolerant of fluctuations in environmental conditions of any species in the Gulf. It is more tolerant to changing salinities than most other species and is found in the mouths of estuaries (Earle, 1972).

Widgeongrass, *Ruppia maritima*, is not a true seagrass, but grows in brackish areas. It is the dominant species of submerged vegetation in the Louisiana coastal area (Chabreck et al., 1968).

Manatee grass, *Syringodium filiforme*, grows throughout the Gulf in muddy sand at depths to at least 25 feet (Earle, 1972).

The environmental role of seagrass has been thoroughly outlined by Humm (1973) as follows:

(1) They serve as a sediment trap, stabilizing bottom sediments from the water's edge to a depth of 6 to 16 meters or more.

(2) They carry on primary productivity that may considerably exceed that of benthic algae or phytoplankton in the same area.

(3) They serve as a direct food source for a few animals, including sea urchins, sea turtles, manatees, and certain herbivorous fishes; partially decomposed leaves in the form of detritus serve as a food for a wide variety of detritus-feeders, especially invertebrates but also some fishes.

(4) They serve as a refuge, and a source of food organisms as well, for juveniles of many species of seafood organisms including shrimp, crabs, bay scallops and fishes.

(5) They provide a habitat for a certain assemblage of invertebrate species that burrow or grow attached to the leaves; these organisms might otherwise be uncommon or absent in habitats that lack seagrasses.

(6) They provide an important substrate for attachment of scores of species and a significant biomass of benthic algae that otherwise would be rare or absent in an area.

In areas where seagrasses have been removed, the habitat rapidly declines from a fertile environment to a virtual desert (Wood et al., 1969).

(8) Estuaries and Embayments

The estuarine waters of the northern Gulf coast, from the Texas-Mexico border to the tip of the Florida peninsula, cover an area in excess of 6 million acres. More than 60% of this acreage is located along the Louisiana-Mississippi coast. The importance of estuaries to the viability and survival of coastal flora and fauna has repeatedly been emphasized by numerous spokesmen and authors from the scientific community. In general, the estuaries and bays of the Gulf coast support, either directly or indirectly, nearly one-third of the U. S. fisheries (U. S. Dept. of Commerce, 1974).

Estuaries and bays are highly productive ecosystems. They receive nutrients from upland areas via major river systems, especially during spring flooding. They also receive the nutrient wash-out from tidal flushing of the salt marsh, particularly in mid-winter when marsh grass of the previous season is decomposing. The dynamics of this system holds for the estuarine areas of the central and eastern Gulf. Diagrammatic cross sections including a listing of representative invertebrate species are shown in Figures and (Collard and D'Asaro, 1973). Figure 111 typifies the region from Louisiana to Cedar Key, Florida, although many of the species listed may be found at significant distances west of Louisiana and south of Cedar Key. Figure 112 summarizes the fauna found in bays in the southeastern Gulf which show a greater affinity to the fauna characteristic of the West Indies.

West of Louisiana, the Texas coast portrays a different system of bays and estuaries. Here, all but one of the eight major bay systems - most of which are interconnecting, are fronted by an almost continuous chain of barrier islands and peninsulas. Consequently, most of the bays reflect only a minor influence from Gulf waters; furthermore, in the semiarid climate of South Texas, where fresh water drainage is negligible, hypersaline (salinities greater than 40 parts per thousand) conditions persist in the bays and lagoons. In general, a low-to-high salinity gradient exists along the Texas coast from east to south, respectively (U. S. Army Corp of Engineers, 1973). The invertebrate fauna characteristic of these bays is given in Table 50 .

The most important invertebrates to the Gulf coast include the shrimps, oyster and blue crab. The greater part of the diet of these valuable commercial species consists of detrital or decomposed material.

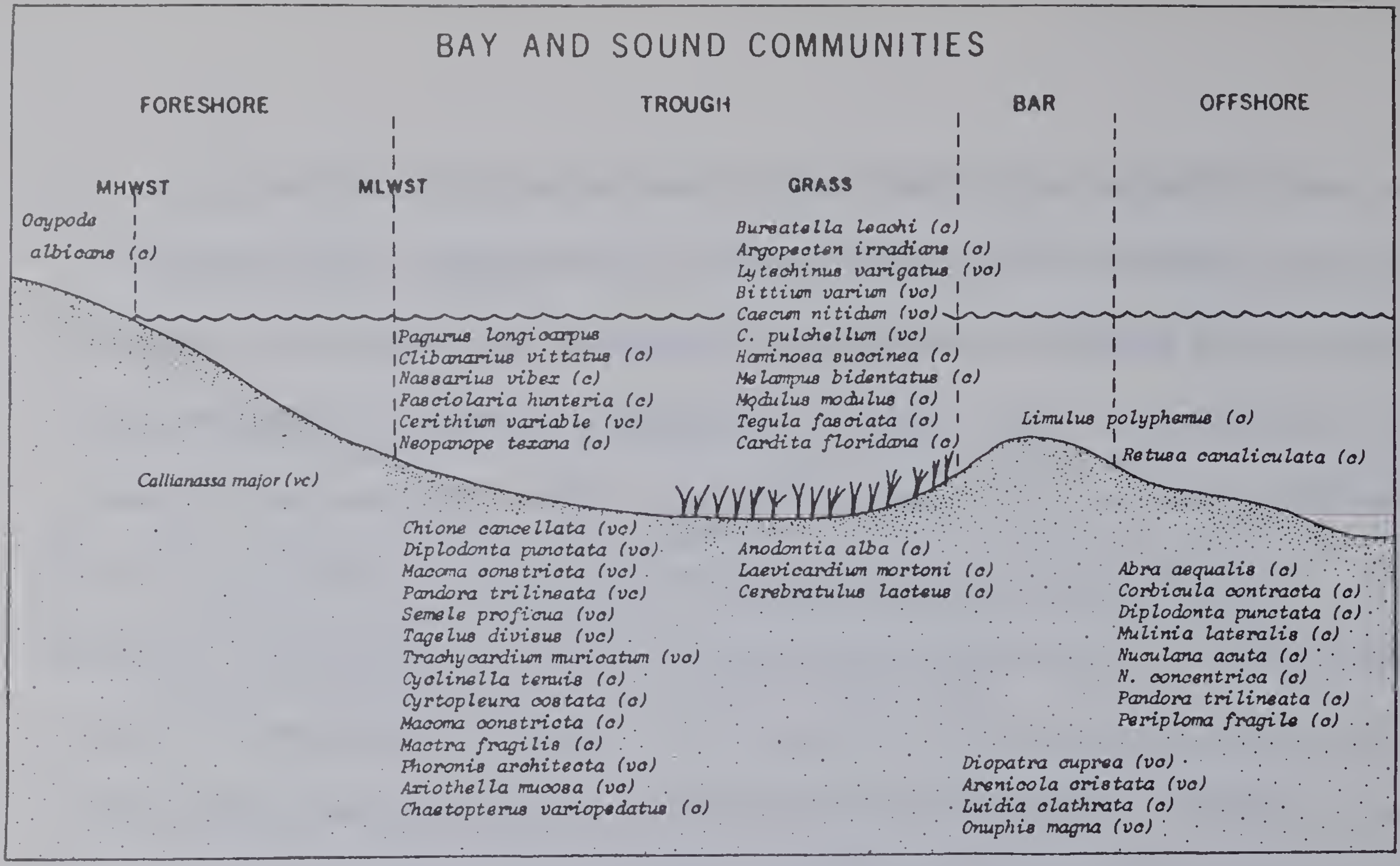

Figure 111. Bay and sound communities: Carolinian affinities. Most species listed are wide ranging, occurring in sand and grass. Typical of northern Gulf Coast from Louisiana to Cedar Key, Florida (from Collard and D'Asaro, 1973).

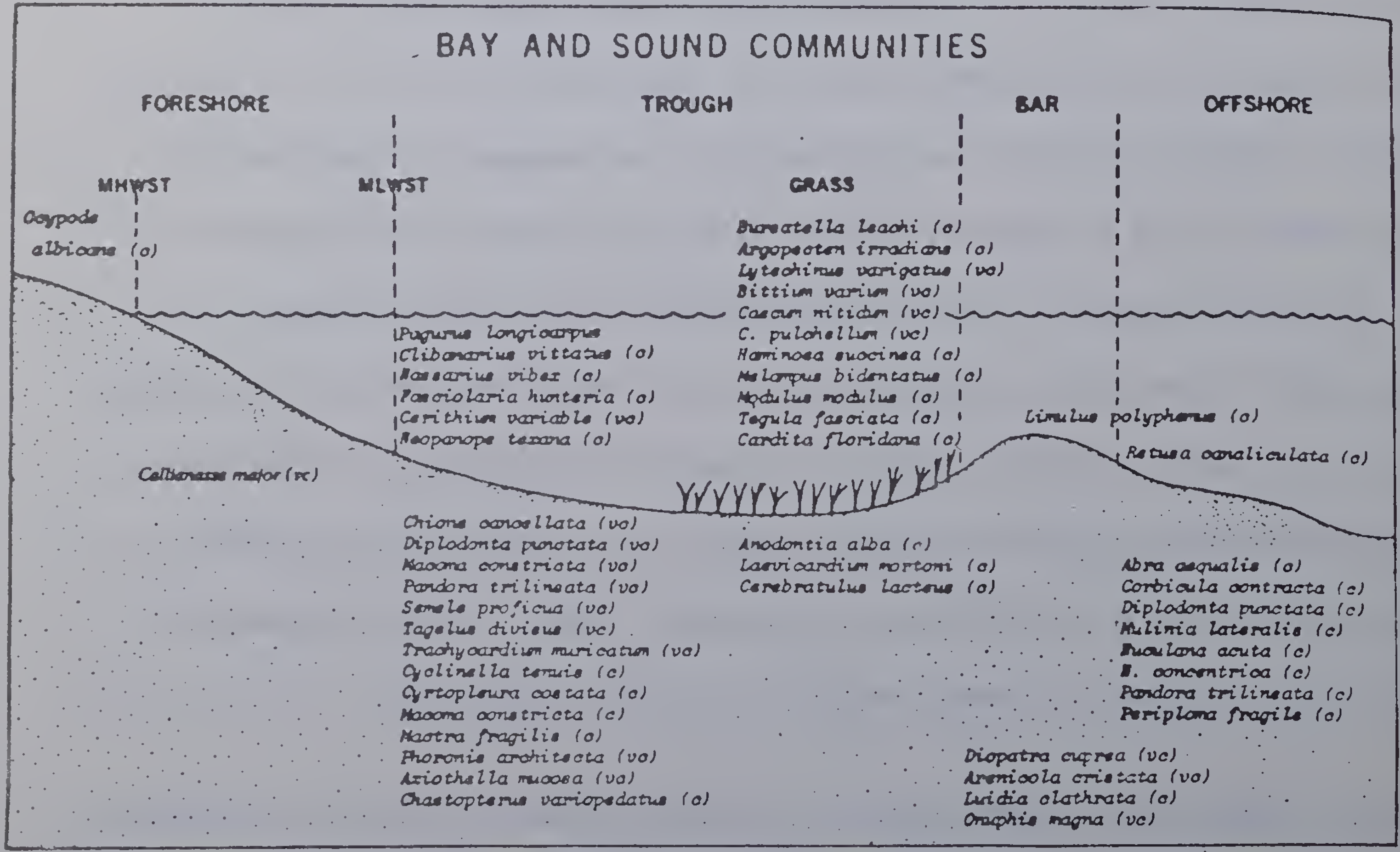

Figure 112. Bay and sound communities: West Indian affinities. The greatest concentration of animals occurs in the turtle grass community. Scattered south of Cedar Key, common south of Tampa Bay (from Collard and D'Asaro, 1973).

The three commercially important species of penaeid shrimp are dependent upon the estuaries for much of their life cycle. The white shrimp, _Penaeus setiferus_, usually spawns offshore, then the larvae are carried into the estuaries where they eat, grow, and return, in several months, to the Gulf of Mexico as adults. White shrimp frequent waters of salinity as low as 0.4 o/oo. The major production of white shrimp occurs around the mouth of the Mississippi. Brown shrimp, _P. aztecus_, are found mostly in the western and northwestern Gulf and exhibit a life cycle similar to the white shrimp, wherein the young occur in waters of salinity as low as 0.8 o/co. Thus, it is quite evident that shrimp can invade the inner most reaches of the brackish and intermediate marshes of the Gulf coast during their life cycle. The pink shrimp, _P. duorarum_, is common to the Eastern Gulf and Atlantic Florida coast. This latter species is not as euryhaline (tolerating a wide salinity range) as the other two and does inhabit waters of salinity less than 2.7 o/oo (Gunter, 1956; 1961).

The oyster, _Crassostrea virginica_, and the brackish water clam, _Rangia cuneata_, are two common and important members of the infauna (living in sediment) of the coastal bays and estuaries along most of the Gulf coast, but their greatest abundance is in the north-central region.

In the estuaries, the oyster lives in depths from 30 cm above mean low water level to 12 m below mean low water level in salinities ranging from 10 parts per thousand (o/oo) to 30 o/oo (Stone, 1972). Oysters consume phytoplankton as well as detritus and live in "bars" or elevated communities where sufficient circulation provides a continual source of phytoplankton. Though they spend most of their juvenile and adult lives on the bar as sessile (non-locomotive) organisms, as larvae they swim freely in the water column for 3-4 weeks before settling as spat. An oyster reef is diagrammed in Figure 111.

The brackish water clam, *Rangia cuneata*, is found primarily in the low-salinity back-bays and is distributed along most of the Gulf coast. This organism prefers less saline waters than the oyster and consumes both detritus and plankton. In turn, *Rangia* are eaten by the freshwater drum, *Aplodinotus grunniens*, and the black drum, *Pogonias chromis* (Darnell, 1958). *Rangia* and the associated organisms of the low-salinity habitat are listed in Table 50.

Table 50.

River-Influenced, Low-Salinity Assemblage

(Modified from Parker, 1960)

Species	Comparative Abundance
PELECYPODS	
Rangia cuneata	Common in beds. Tend to have largest size in lowest salinity
Rangia flexuosa	Less abundant. Prefers higher salinity and shallower water

Table 50, cont.

Polymesoda carolinensis	Missing from Mobile, east, and Matagorda Bay, west and south not in fresh water as R. cuneata
Macoma mitchelli	Common in all low salinity lagoons and estuaries
GASTROPODS	
Littoridina sphinctostoma	Common in some localities. Replaced by other small hydrobiids elsewhere
CRUSTACEANS	
Callinectes sapidus	Very common at certain seasons, Ranges to nearshore gulf
Macrobrachium (various species)	Range some distance up rivers

A consumer of decomposing animal matter, the bluecrab, *Callinectes sapidus*, is a resident of the fresh and saltwater marshes of the Gulf coast for the entire year.

The great majority of sport and commercial fishes are dependent upon the marsh-estuary ecosystem at some time during their life cycle. These fishes and some of the more common coastal fauna which are dependent upon the estuaries are listed in Table 51 .

Table 51.

A partial list of some common
estuarine-dependent species of fishes and shellfishes
(from U. S. Army Corp of Engineers, 1973)

Scientific name	Common name
Trachinotus carolinus	Pompano
Mugil cephalus	Striped mullet
Leiostomus xanthurus	Spot
Cynoscion nebulosus	Spotted seatrout
Sciaenops ocellata	Red-drum
Cynoscion arenarius	White seatrout
Pagonias cromis	Black drum
Brevoortia patronus	Largescale menhaden
Brevoortia smithi	Menhaden
Micropogon undulatus	Atlantic croaker
Scomberomorus maculatus	Spanish mackerel
Archosargus oviceps	Gulf sheepshead
Paralichthys lethostigma	Southern flounder
Penaeus aztecus	Brown shrimp
P. setiferus	White shrimp
P. duorarum	Pink shrimp
Macrobrachium ohione	Giant freshwater shrimp
Xiphopeneus kroyeri	Seabobs
Procambarus blandingi	Crayfish

Table 51,(Cont.)

Callinectes sapidus	Blue crab
Menippe mercenaria	Stone crab
Crassostrea virginica	American oyster
Macrocallista nimbosa	Sun-ray venus clam
Argopecten irradians	Bay scallops
Mercenaria mercenaria	Quahog

Only three species of marine mammals can be expected to utilize the bays or estuaries in the Gulf of Mexico to any extent (Caldwell and Caldwell, 1973). Of these, the bottle-nose dolphin is the only one that occurs throughout the Gulf in inshore waters. It may be encountered at any one point at any time of the year, but there is evidence to suggest that short migrations do occur so that it may be more common in one locality at one time of the year than another.

The manatee is the only marine mammal regularly and exclusively utilizing the estuarine habitat. It is primarily an inhabitant of the Florida coast, but may occasionally range to the central Gulf coast.

The California sea lion has been introduced to the Gulf of Mexico and ocassionally occurs in the bays and shorelines of the eastern Gulf. However, the species is not abundant and probably does not maintain a breeding population near the Gulf States.

The principal value of bays to wildlife is the habitat they provide to waterfowl. Gusey and Maturgo (1973) have summarized data pertaining to migration corridors used by diving ducks wintering the Gulf of Mexico.

> The "Eastern Plains Corridor" originates in western Manitoba and eastern Saskatchewan and terminates on the lower Texas coast. Most of the divers using this corridor are redheads, a population comprising almost 3/4 of the redheads in North America which fly this corridor to reach wintering grounds on the Laguna Madre on the lower Texas and upper Mexican coasts. These are joined by lesser scaups and canvasbacks also using this corridor.
>
> The "East Texas Corridor" is a small corridor used by a small number of divers, principally lesser scaups, ring-neck ducks, and canvasbacks, moving from the eastern Dakotas to the Texas coast between Sabine Lake and Matagorda Bay.
>
> The "Missouri River Corridor" extends from central South Dakota to the Gulf coast of Louisiana. Usually lesser scaups, ring-neck ducks, redheads and some canvasbacks, move along this route. Of these, most winter on the Louisiana coast, on the Lacassine National Wildlife Refuge, and in the vicinity of Lakes Ponchartrain and Borgne.
>
> A small flight corridor, the "Prairie Corridor", extends from southwestern Minnesota to the Louisiana coast, a route followed by some ducks eastward to Florida. Significant concentration points for birds following this route, lesser scaups, ring-neck ducks, canvasbacks, lie east of Grand Chenier and west of Marsh Island, the Mississippi Delta, and Wax Lake southwest of Morgan City.
>
> Two other corridors, the "West Florida corridor" and "Mobile Bay Corridor" terminate at points along the Gulf coast east of Louisiana, primarily Mobile Bay, Alabama, and the Noxubee National Wildlife Refuge in eastern Mississippi.

(9) Beaches

Much of the northern Gulf coastline is protected from the full force of oceanic waves by barrier islands. The seaward margins of these islands, which are exposed to waves formed at sea, are called high energy beaches. Organisms living in such areas are adapted to survive the scouring force of wave action by burrowing in the sand. The beach flea, Emerita, and the bivalve, Donax, (among others) can bury themselves almost instantaneously. This ability enables them to live directly in the surf zone (Collard and D'Asaro, 1973). Figure depicts the species commonly found on the high-energy beaches east of the Mississippi; however, many of the same invertebrates are characteristic of the beaches along the barrier islands of Texas (Parker, 1960).

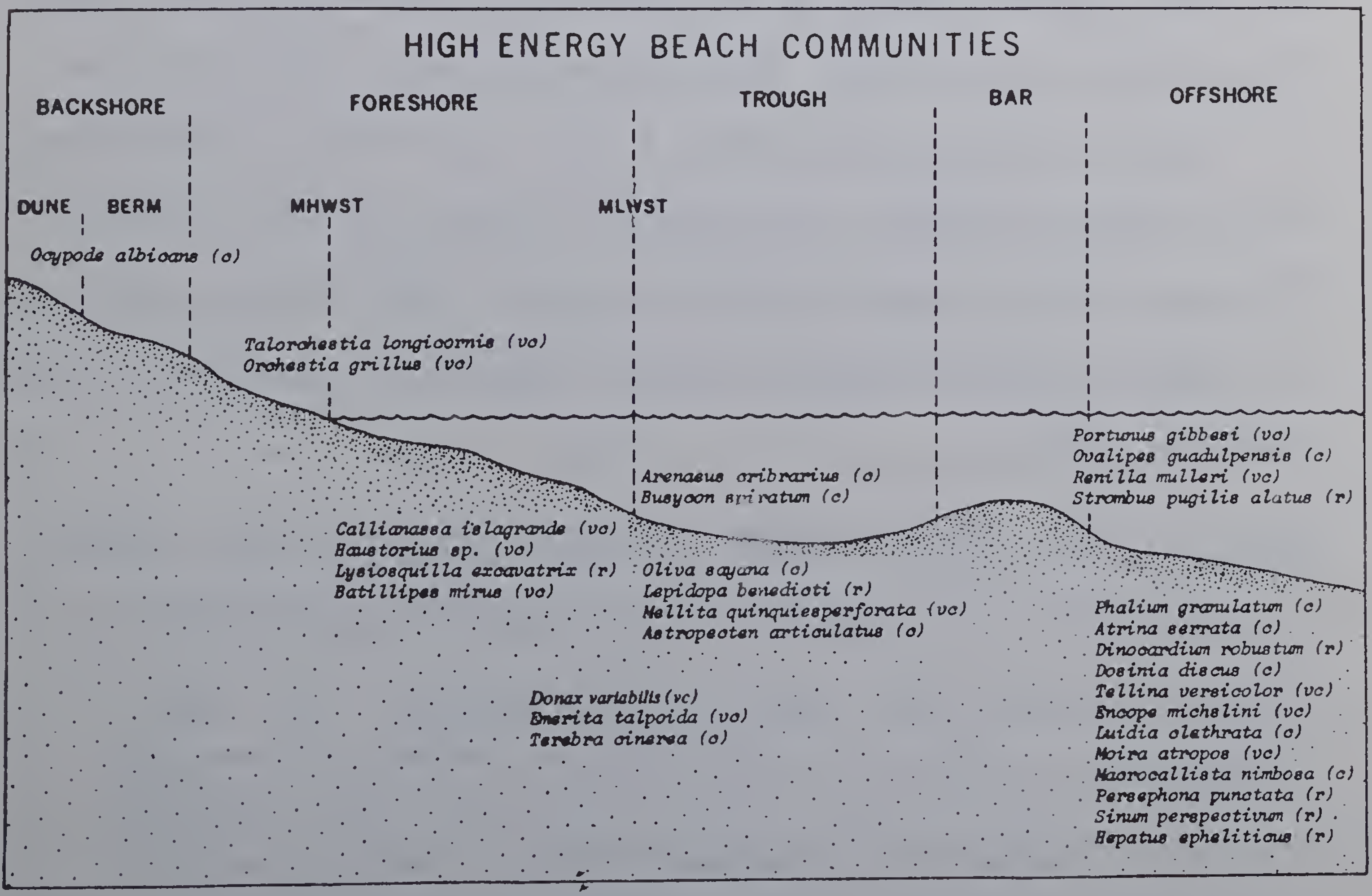

Figure 113. High Energy Beach Communities. Composition of these communities is essentially the same from the Mississippi barrier islands to Cape Sable, Florida (from Collard and D'Asaro, 1973).

c. Resources of the Coastal Zone

(1) Land Use

(a) General

Texas: The Texas Gulf Coast is characterized by a nearly continuous chain of offshore barrier formations which provide hurricane protection to the heavily indented main shoreline, and the extensive series of inland bays. Both the mainland and barrier formations are highly variable in land use types and intensities.

On the barrier formations, land use is generally a function of proximity to population centers and availability of access. Most have sandy beaches facing the Gulf and are suitable for beach-oriented recreation activities. The first significant formation on the south coast is Padre Island, most of which is occupied by the Padre Island National Seashore. The Seashore retains a primitive condition except for recreation facilities at its north end, but areas to the north and south are being rapidly developed into residential and commercial uses.

Mustang Island is also a highly developed recreation center for the Corpus Christi area, with beach homes, resorts, water-oriented recreation facilities and commercial establishments. St. Joseph Island on the contrary, is less developed, and used for ranching and private recreation. Matagorda Island is remote, accessible only by boat or aircraft, and much of the island is occupied by a gunnery range. Its remainder, as well as most of Matagorda Peninsula is rather primitive, principal land uses being ranching and limited recreation. Galveston Island and Bolivar Peninsula contain the City of Galveston and its surroundings, and are both highly developed. This region is experiencing rapid subdivision of its once sparsely settled grazing areas into summer and permanent homes, recreation and commercial developments.

On the Texas mainland, land use ranges from undeveloped, to massive industrial centers. The southern third of the mainland coast is largely undeveloped, although a number of small towns dot the coast. The first significant developed area is Corpus Christi, the largest city on the coast, consisting of 16 miles of urbanization. It is an important seaport and industrial center for petroleum and agricultural products, and a major tourist and convention center. To the north, the bay shorelines are partially developed with permanent and summer homes, fishing and hunting camps, and oil field support activities. The small cities and communities of the area cater to tourists, hunters, fishermen and other water-oriented recreation areas, but further north the shoreline again reverts to a mostly undeveloped character for great distances up to the Galveston Bay area. This bay contains the largest concentration of shoreline development on the entire Texas coast, consisting of commercial and residential uses, and large industrial complexes which relate to fishing, shipping, offshore gas and oil exploration and production. To the north, the shoreline is again mostly undeveloped, the area used for limited public recreation.

In the more general coastal zone, which includes coastal and some inland counties, agriculture is extensive, with about 41% of the land dedicated to such use. It is concentrated in the original prairie grasslands of the central and upper coastal zone, and becomes less prominent to the south because of decreased rainfall. About 42% of the area is devoted to ranching. This activity is concentrated in more arid regions of the south, and the low lying coastal marshes. The grazing of beef cattle is the principal use of the range lands.

The principal urban and industrial concentration is in the upper coastal zone, where there is diversified land and water use. This region which includes the Houston-Galveston areas contains extensive mineral resources, especially oil and gas, and chemical raw materials, which supports one of the largest petroleum and petrochemical centers in the world. It also has major port facilities, extensive waterways and ship channels.

Louisiana: The general characteristic of the Louisiana coastal zone has resulted in a very extensive and largely undeveloped land use pattern along the shoreline, with more intensive uses concentrated in those inland areas more suitable for development. The shoreline is heavily indented, particularly in the eastern half, composed of marsh lying at or near sea level, pocked with shallow lakes and bays and interlaced with a network of channels and canals. Most of this is saltwater marsh, either partially submerged or subject to tidal overflow, and not suitable for general development or activity. This marsh occupies about 3.7 million acres in a broad band across most of the state's interface with the Gulf.

The coastal marshes and the general lack of sandy beaches preclude beach-oriented activities in most areas, and the general lack of access further limits shoreline use. Existing land use consists of small communities oriented to the seafood industry, and to support of offshore oil and gas operations. Severe developmental constraints, including susceptibility to hurricane surges, have kept permanent shoreline developments to a minimum.

In spite of this general lack of shoreline development and land use, the larger coastal zone has been a major focal point for the state's population and industrial expansion for many years. Because the interior coastal zone environment also possesses constraints to many activities and developments, such expansion has generally been concentrated in major nodes. Lake Charles and Lafayette are centers for trade and commerce, including agricultural commodities and timber, and more recently they have become major service areas for the offshore gas and oil industry. Baton Rouge, is an education, industrial and government center, its principal industrial activity being the refining of oil. New Orleans, which contains about 30% of the state's population, is a thriving port complex and center for the tourist, food processing and chemical industries.

Because of natural gas availability for fuel, crude petroleum, water transportation and existing industry in the coastal zone, it has absorbed most of the state's recent expansion in industrial activity and population, and this trend is expected to continue. Industry in the coastal zone is dominated by petroleum refining, petrochemical production, ship building, food processing, (including seafood) and primary metals, with Petroleum refining and petrochemicals being the most significant. Activities relating to the extraction, transportation and processing of oil and gas (including the offshore component) are significant land uses in the coastal zone. The majority of oil and gas wells are in swamp and marsh areas, (which use is often coextensive with other land uses), and most of the state's total production comes from the coastal zone parishes.

Agriculture is a significant land use throughout the coastal zone, with rice production predominating in the southwestern portions, sugar cane along the major rivers, and soybeans a generally distributed crop. The beef cattle industry is also an extensive land use in the coastal zone, but most concentrated in the rice growing areas.

Mississippi: The Mississippi portion of the Gulf Coast includes three counties, the main shoreline of which is slightly indented, consisting of marsh areas and artificially maintained beaches. There are sand beach barrier formations which partially enclose an inland water called the Mississippi Sound. The coastline on the Sound is generally highly developed, while the barrier formations are generally undeveloped.

Little differentiation remains between communities along the coastline, where a high density urban corridor has recently taken form due partly to great expansion of the tourist-recreation industry. The only major breaks in this linear development are the result of natural features such as bays, estuaries, rivers, and tidal marshes. This urban and urbanizing link of communities centered around Gulfport-Biloxi has utilized the transportation, recreational and other amenities of the Mississippi Sound to develop their economy. While earlier settlement patterns utilized higher ground, the extremely rapid residential, industrial and commercial growth of the past 20 years has caused encroachment on wetlands and marginal areas. Transportation (especially port facilities), seafood processing, oil refining, and the tourist-recreation industries are predominant land uses along the coast.

Inland, land use is extensive, being generally undeveloped and rural in character, with greater distances separating the urbanized areas. Agriculture and commercial forest land are predominant uses.

Alabama: Two counties in Alabama border the Gulf of Mexico, but the main land-water interface is the deeply indented Mobile Bay, which is almost entirely enclosed by barrier formations. Topography has imposed historical constraints on development patterns and land use allocations. Mobile Bay and its delta to the north, and other lower elevations subject to flooding are generally timbered and undeveloped, while development has been directed to higher elevations, both along the coast and inland.

The mainland shore is a marsh - beach mix, the barrier formations are sandy beaches. The coastal areas, especially the barrier formations are coming under increased pressure for commercial and recreational development. Many smaller communities exist which consist of residential areas, cottages, hotels and motels which accomodate tourist and seasonal visitors.

The urban core of the region is the Mobile area, but an interrupted band of urban development encircles the entire bay, and extends a considerable distance inland. The core consists of industrial, commercial and residential developments, and the larger urban area follows a semi-concentric pattern around the commercial-industrial core. The Mobile area is a major industrial community, with paper and chemical manufacturing predominating. It is also a transportation center with the port of Mobile a highly significant land use.

Inland, land use is extensive. The more southern areas are agriculture, while a commercial forest - agricultural mix characterizes areas to the north.

Florida: The Florida Gulf Coast is the longest and most diverse of any Gulf state. It alternates from sandy mainland beaches, to barrier formations which enclose extensive inland bays, to large swamp and marsh areas which front directly on the Gulf. The distribution and variability of land uses along and behind the coast is a direct function of these physical differences in coastal characteristic.

The coast of the "panhandle" is characterized by sandy beaches and barrier islands which separate the Gulf from a series of estuaries. Most of this length is suitable for general beach activity. The regions development is focused on its shoreline areas; with naval activities, shipping and marine resources, predominating. Industrial development has also gravitated to the area because of transportation and production facilities. More recently, land use dedicated to the tourist and recreation industry has greatly increased. The shoreline uses are highly variable. The Pensacola Bay region contains a long uninterrupted stretch of urbanized shoreline, while Santa Rosa Island exhibits a mix of highly developed residential and tourist-oriented establishments while much of it remains undeveloped recreation land as a result of the Gulf Islands National Seashore. Fort Walton Beach is another center relying heavily on tourist and beach-oriented activities. The most intense tourism and recreation related land use is on the Gulf west of Panama City, where an almost unbroken commerical strip development consisting of motels, condominiums, restaurants, associated amusements, summer homes, etc. has occurred.

East of Panama City, however the quality of the beach deteriorates, coastal land use becomes much less intense, populations are low, and only a few summer homes exist.

From the panhandle south to north of Tampa Bay, the coastline is irregular, there are no barrier formations, beaches and semi-enclosed bays are rare, and salt marshes line the shores and penetrate inland several miles. Further inland are freshwater marshes and swamps. Land use is extremely extensive, population densities are among the lowest in the state, and most of the area remains as commercial forest land. Very little use is made of the shoreline, due to its inaccessibility.

From north of Tampa Bay to nearly the southern tip of the Florida peninsula, the coast is again characterized by sand beaches on the Gulf, with numerous barrier islands separating the Gulf from a series of bays and lagoons, often lined with mangrove swamps. The major urban area in this stretch is the Tampa-St. Petersburg complex, with a population of over 1.5 million. Initial settlements were established along the shoreline areas, and recently tourists and retirees have come to the region in large numbers. Industrial expansion has also occurred due to the transportation advantages of the coastal zone, which enforces the historic shoreline-oriented development pattern. Presently, 82% of this region's developed land is in its coastal zone and the former nodal pattern has coalesced into a linear pattern along the coast, and the barrier formations. This development extends along a coastal front four counties long, broken only by Tampa Bay.

The extreme southern Florida Gulf coast is characterized by mangrove swamps and islands, and tidal marshes. Inland areas are mostly swamp, population densities are very low, and land use extensive.

(2) Recreation Resources

a. Outdoor Recreation Areas, Historical and Archeological Sites

The Gulf coast offers a wide variety of recreational opportunities. The natural setting provides habitat for numerous species of fish sought by sport fishermen; attractive beaches for swimming, sunbathing, etc.; and a variety of landscapes (dunes, marshes, forests) for the observation of wildlife and scenery. The recreational opportunities of the Gulf are available not only to residents of the area but support a substantial tourist industry as well. In addition to the natural setting the coastal zone has numerous historical and archeological sites of scientific and educational value.

Following are descriptions of the various kinds of outdoor recreation areas, wildlife refuges and management areas, and historical and archaeological sites. An inventory and a series of maps of the major outdoor recreation areas is included.

National Parks: The National Park Service of the U. S. Department of Interior administers two national parks along the Gulf Coast. These are Gulf Islands National Seashore, and Padre Island National Seashore. These areas have been set aside as units of the National Park System because of the national interest in their natural, historical and recreational opportunities such as camping, swimming, boating, fishing, nature study, picnicking and sightseeing is available at these parks.

Federal Wildlife Refuges: The Bureau of Sport Fisheries and Wildlife of the U. S. Department of the Interior has the responsibility for insuring the conservation of the country's wild birds, mammals and sport fish. The primary purposes of wildlife refuges are to provide sanctuaries for wildlife and fish by preserving breeding grounds and habitat which may be becoming scarce in other areas due to encroachment on natural habitats by agricultural, industrial, and urban development, and to provide opportunities for the scientific study of various species of wildlife and for the management and preservation of their populations. These refuges also provide important opportunities for outdoor recreation, primarily nature study and natural scenery appreciation.

State Wildlife Management Areas: The various state Game and Fish ommissions are responsible for the operation of a number of game management areas which are becoming an important part of the outdoor recreational scene. Due to the increasing demand for hunting and fish- and increasing pressure from development on natural habitats, it is necessary to set aside certain land and water areas for game and fish management purposes.

Aquatic Preserves: The aquatic preserves system is unique to Florida. Florida owns, by virtue of its sovereignty, some 10,000 square miles of submerged tidal lands offshore from its extensive Atlantic and Gulf coastlines and in its numerous bays, estuaries and lagoons. Much of this submerged land supports biological, aesthetic, and other natural features important ecologically and for outdoor recreation, but all of it is potentially vulnerable to major impairment from incompatible development. To set aside certain exceptionally valuable and representative areas for perpetual public enjoyment and to preserve important natural systems, a state-wide system of aquatic preserves was established by formal dedication of the sovereignty lands involved. The subsequent management program for the preserves emphasized protection of the existing natural values as well as promotion of compatible outdoor recreational uses, such as boating, fishing, skin diving, and sightseeing. The State of Florida Board of Trustees of the Internal Improvement Trust Fund has management responsibility at present.

State Parks: These facilities in all five states are relatively spacious areas established primarily to preserve natural features of exceptional quality, historic, archeological, scientific, or other distinctive characteristics and have been developed for high density use. The state parks are under the jurisdiction of the Division of State Parks in each of the five states.

Archeological Sites

The Gulf coast contains large numbers of archeological sites which provide evidence essential to the understanding of aboriginal cultures in the area. The known sites along the coast represent the various stages in cultural development of the prehistoric inhabitants. Archeological evidence found in these sites includes shell middens, villages, burial mounds, pottery, tools and weapons.

There are known archeological sites in all the coastal counties and parishes of the area of concern. A large proportion of the sites are concentrated near the coast and along riverbanks and bay shorelines where there was easy access to food sources (fish and shellfish) and transportation routes. It is probable that there are many as yet undiscovered archeological sites in the coastal area, and likely places for their discovery are in areas such riverbanks, deltas, and islands.

It is also possible that submerged sites of archeological value may be found offshore on the continental shelf or in embayments. Since man has inhabited the Gulf coast region for thousands of years, there was human occupation in the area at a time when the sea level was much lower than it has been in historic times. Emery and Edwards (1966) give evidence that nomadic hunters and possibly fish and mollusk eaters may have lived in areas of the Atlantic continental shelf which are now submerged. They point out that the most likely areas for finding submerged archeological sites are areas "which have received little or no cover of postglacial sediment and where rivers formerly crossed the shelf."

Evidence indicates that since 10,000 years ago there has been a minimal rise in sea level of 40 to 60 meters, which would support the probability that some portion of the continental shelf in this region may have supported human habitation in the past.

A study of archaeological resources in the Texas coastal zone (Briggs, 1971) states that there are 1,339 sites on record in their study area which included 35 counties in the Texas coastal lowlands. The density of the known sites varies considerably throughout the area, but this is thought to be due to the varying intensity of study within the area.

In Florida, the Coastal Coordinating Council has mapped approximately 350 known sites in the Gulf coastal counties.

Numerous sites exist in the coastal parishes of Louisiana and the coastal counties of Mississippi and Alabama.

Because of the sensitive nature of the location of archaeological sites and the large number of sites, it was not possible to plot the known sites.

Historic Sites

The numerous historic sites located on the Gulf Coast date from the earliest Spanish explorations of the area in the early 1500's. A number of these sites are included in the National Register of Historic Places or are National Historic Landmarks. Still others have been submitted to the National Register and are pending approval, and others have been selected by the State Boards of Review for submission to the National Register. These sites include forts, churches, buildings of architectural interest, homes of important historic figures, sites of important battles, and Indian Villages.

b. Sport Fishing

Saltwater sport fishing is one of the most popular outdoor recreation activities in the Gulf region and is a significant factor in the economy of the coastal zone. The sport, fishing activity, catch, and value has been inadequately recorded. Recently the National Marine Fishery Service has established two sport fishing laboratories in the Gulf area and has undertaken, with their port sampling of commercial products, the gathering of sport fishing data. Therefore, these renewable resources will be better defined in succeeding years. At the present time very little data is available for the Gulf of Mexico area. However, information is available from several nationwide surveys for the Gulf region.

Estimates of the sport fishing effort in the Gulf of Mexico have been made by the National Marine Fisheries Service in the *1970 Saltwater Angling Survey* (U. S. Dept. Commerce, 1973). Saltwater sportfishing was defined for the purpose of the *Survey* as "all fishing in the oceans, bays, estuaries, and tidal portions of rivers. The number of geographical divisions for reporting the catches was limited to seven, which were chosen to coincide with biogeographical areas rather than political subdivisions. In the *Survey*, the Gulf of Mexico was divided into East Gulf and West Gulf with the Mississippi River as the boundary.

According to the *Survey*. there were 2.3 saltwater anglers in the Gulf during 1970. These anglers caught 486 million pounds of fish and spent $405 million. The fishing effort and pounds of catch in the Eastern Gulf was approximately double that in the Western Gulf. The sports catch was approximately 29 per cent of the total poundage of

756

Gulf fishery landings. The data fall within the estimation of Taylor (Taylor, J. L., et.al. 1973) who predicted that sport fish landings in the Gulf would approximate one-third to one-half the volume of commercial landings (2 million pounds). The sportsman expenditure was 2.4 times the commercial dockside value (Dept. of Commerce, 1973).

Sport fishermen in the Gulf have fishing access by bridges, causeways, and artificial reefs. Some individuals may use their own private boats, or may fish from party or charter boats. There are numerous fishing piers, both public and private along the Gulf coast from Missippi to Florida. Although statistics are not available to indicate the intensity of use of fishing piers as differentiated from boat fishing, it is apparent from the number of fishing piers and from the number of people observed using them that this is a very popular means of fishing.

Party boat fishing is characterized by the use of a large boat in the range of 55 to 65 feet carrying a large number of people. Bottom fishing consumes the majority of fishing time, although less often drift fishing and trolling methods are used. Party boats usually charge a set fee per person and may require a certain minimum of passengers aboard before they make a trip.

Charter boat fishing is characterized by the use of a smaller boat about 30 to 45 feet in length, carrying up to 6 or 8 persons. Trolling is the primary method used.

In recent years, the establishment of artificial reefs has become popular in the Gulf of Mexico. These artificial reefs, made of old car bodies, tires, concrete pipes, ships, rubble, and numerous other materials provide additional surface area of hard substrate on which numerous types of algae and invertebrate species may grow. These organisms are available as food for foraging species, which in turn, attract predatory fishes. In addition to the expanded food chain and trophic food level potentials, the artificial reefs serve as refuge, protection, and orientation sites. These new sites by attracting and concentrating fish species improve fishing success. However, the population size of fish species are not necessarily increased.

Table 52. INVENTORY OF RECREATION AND HISTORIC RESOURCES OF THE GULF OF MEXICO
(Numbers and Letters Keyed to the Following Series of Maps, Figs.)

National Parks
AA. Gulf Islands National Seashore
BB. Padre Island National Seashore

Federal Wildlife Refuges
A. St. Vincent Island
B. St. Marks
C. Cedar Keys (375 Acres Designated as Having Wilderness Status)
D. Chassahorwitzka
E. Anilote
F. Pinellas
G. Passage Key
H. Jay "N." Darling
I. Pine Island
J. Island Bay
K. Breton Islands
L. Delta
M. Shell Keys
N. Sabine
O. Anahuac
P. Brazoria
Q. San Bernard
R. Aransas
S. Laguna Atascosa

State Wildlife Management Areas and Refuges

Texas

a. J. D. Murphree

Louisiana

b. Rockefeller (Refuge)
c. Louisiana
d. Marsh Island
e. Bohemia
f. Salvador
g. Pointe-Au-Chien
h. Wisner
i. Pass-A-Loutre
j. Biloxi

Mississippi

k. Red Creek

Florida

l. St. Regis
m. La Floresta
n. Blackwater
o. Eglin
p. Point Washington
q. Roy D. Gaskin
r. Ed Ball
s. Liberty
t. Leon-Wakulla
u. Aucilla
v. Tide Swamp
w. Steinhatchee
x. Gulf Hammock
y. Citrus
z. Croom
aa. Richloam
bb. Bull Creek

State Parks

Texas

1. Texas State Park in Jefferson County (Proposed)
2. Galveston Island State Park
3. Velasco State Park
4. Goose Island State Park
5. Copano Bay State Park
6. Port Isabel State Park
7. Brazos Island State Park
8. Port Lavaca Causeway State Park
9. Mustang Island State Park (Proposed)

Louisiana

10. Evangeline State Park
11. Grand Isle State Park
12. Rutherford Beach State Park
13. St. Bernard State Park (Under Development

Mississippi

14. Bucaneer (Proposed)
15. Fisherman's Wharf (Proposed)
16. Magnolia State Park

Alabama

17. Meaher
18. Fort Morgan
19. Gulf Shores
20. Romar Beach
21. Alabama Point

Florida

22. Blackwater
23. Port Pickens
24. Fred Gannon Rocky Bayou
25. John Beasley
26. Grayton Beach
27. Ponce de Leon
28. Basin Bayou
29. Eden
30. St. Andrew
31. St. Joseph
32. St. George Island
33. Ochlochnee River
34. Lake Rousseau
35. Manatee Springs
36. Fort Cooper
37. Anclote Key
38. Caladesi Island
39. Hillsborough River
40. Lake Manatee
41. Torreya

AQUATIC PRESERVES: (All located in Florida)

aa. Fort Pickens
bb. Yellow River Marsh
cc. Rocky Bayou
dd. St. Andrews
ee. St. Joseph Bay
ff. Apalachicola Bay
gg. Alligator Harbor
hh. Waccasassa Bay
ii. St. Martin's Marsh
jj. Caladesi Island
kk. Boca Ciega Sound
ll. Cockroach Bay
mm. Boca Ciega Bay

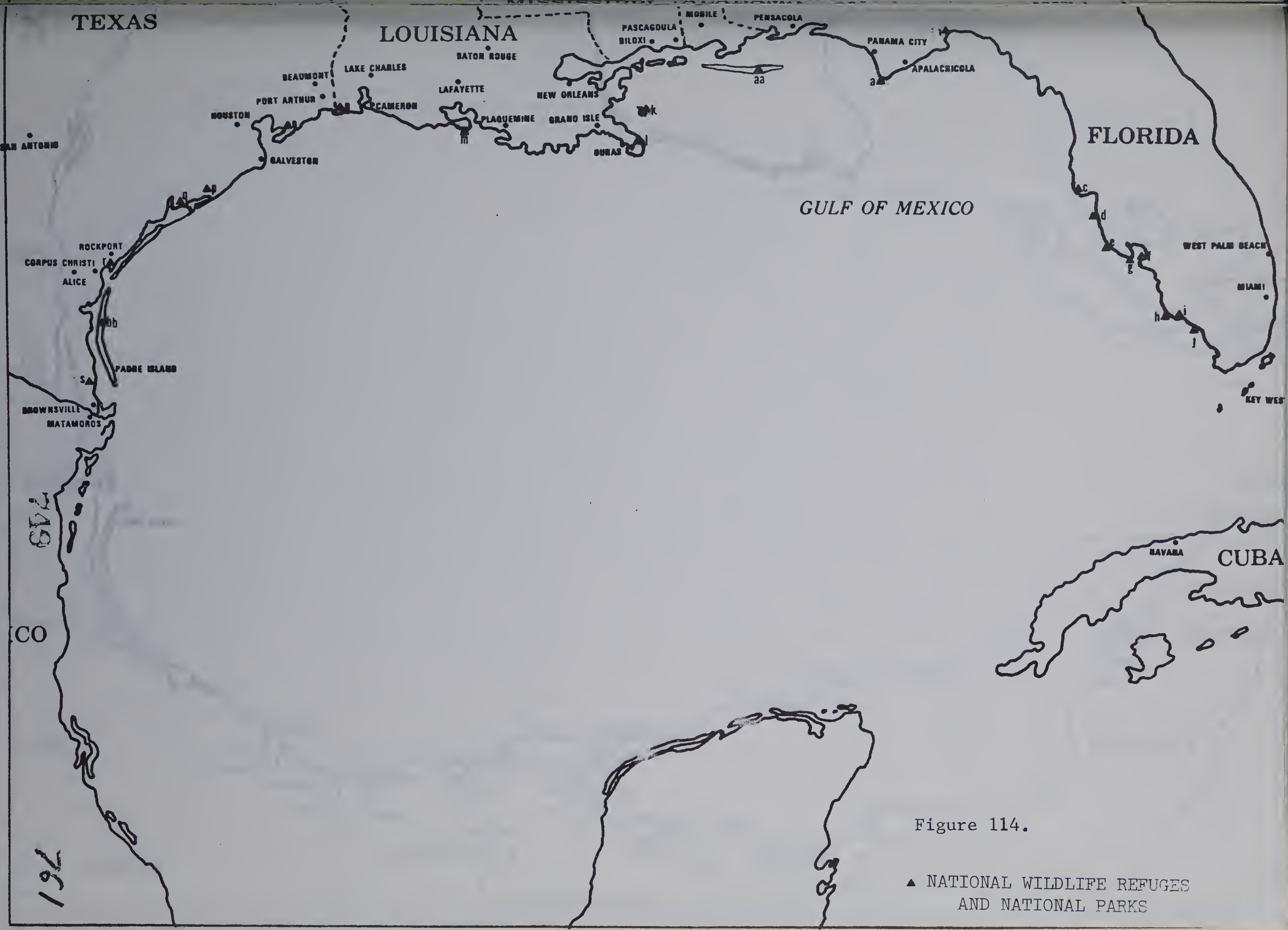
TEXAS
LOUISIANA
PASCAGOULA
MOBILE
PENSACOLA
BILOXI
PANAMA CITY
BATON ROUGE
LAKE CHARLES
BEAUMONT
APALACHICOLA
aa
a
LAFAYETTE
NEW ORLEANS
PORT ARTHUR
CAMERON
HOUSTON
PLAQUEMINE
GRAND ISLE
k
SAN ANTONIO
FLORIDA
BURAS
l
m
GALVESTON
c
q
GULF OF MEXICO
d
ROCKPORT
e
WEST PALM BEACH
CORPUS CHRISTI
f
g
ALICE
MIAMI
bb
h
i
j
PADRE ISLAND
s
KEY WEST
BROWNSVILLE
MATAMOROS
HAVANA
CUBA
CO
▲ NATIONAL WILDLIFE REFUGES AND NATIONAL PARKS

Figure 114.

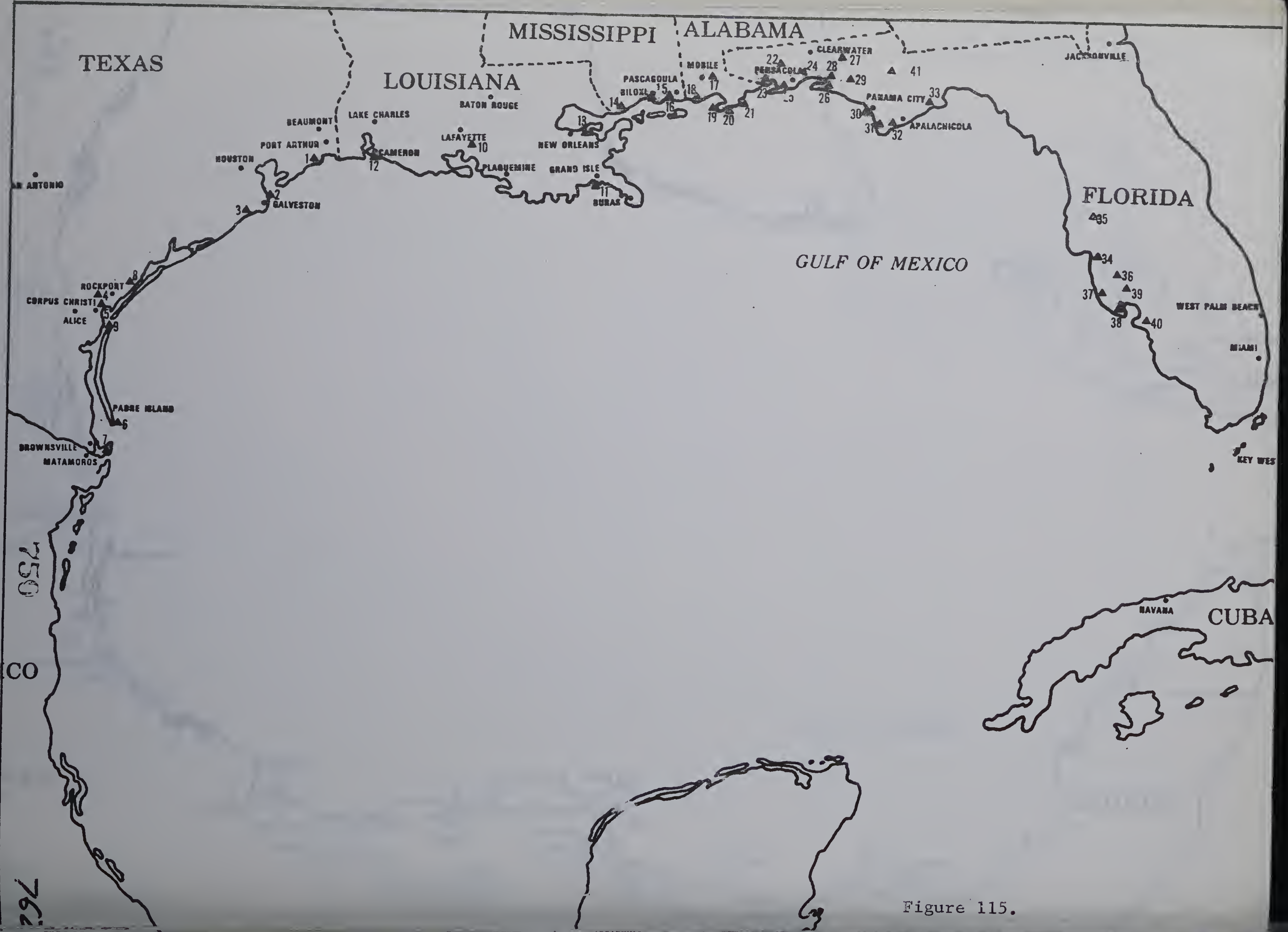
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Figure 115.

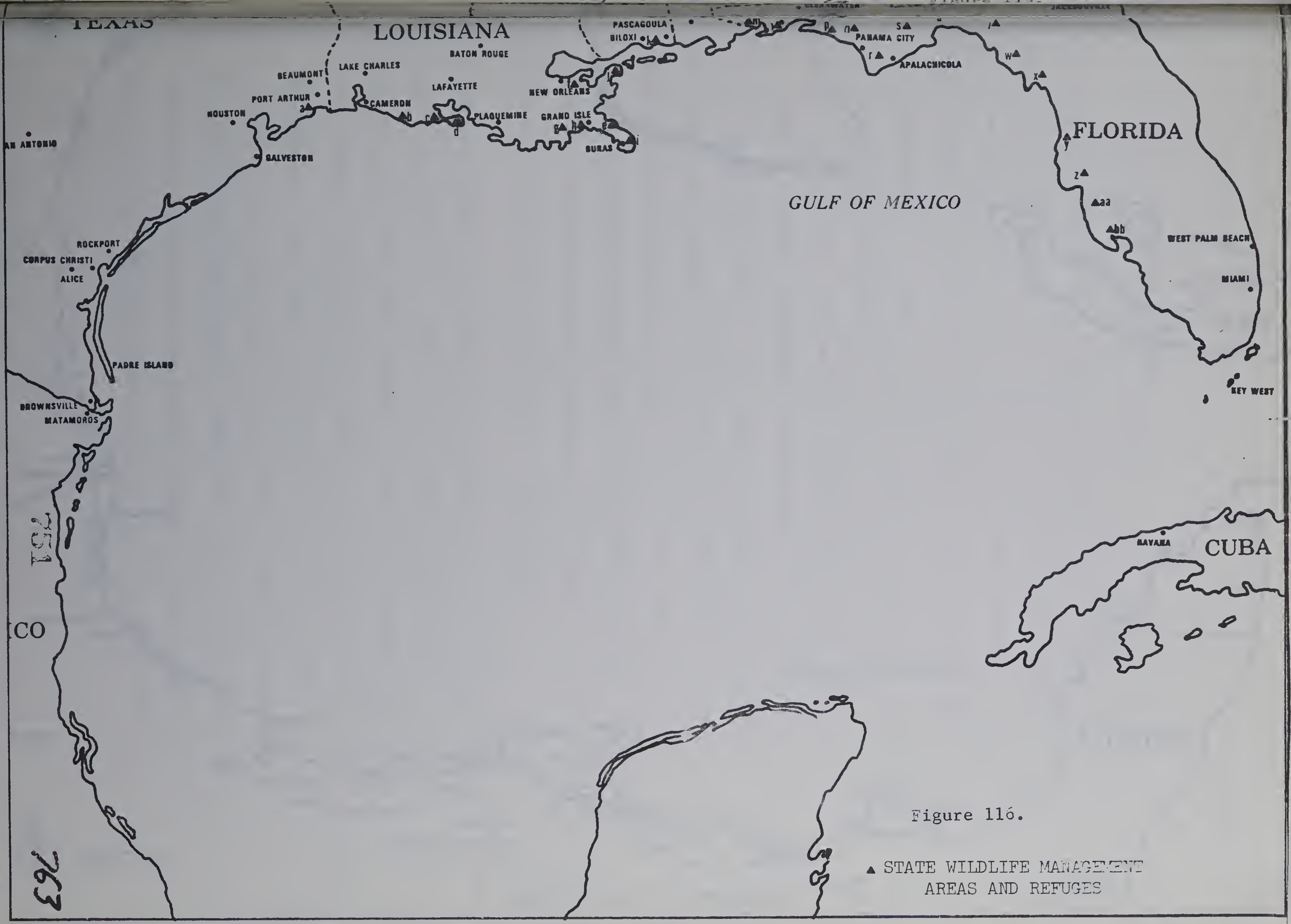
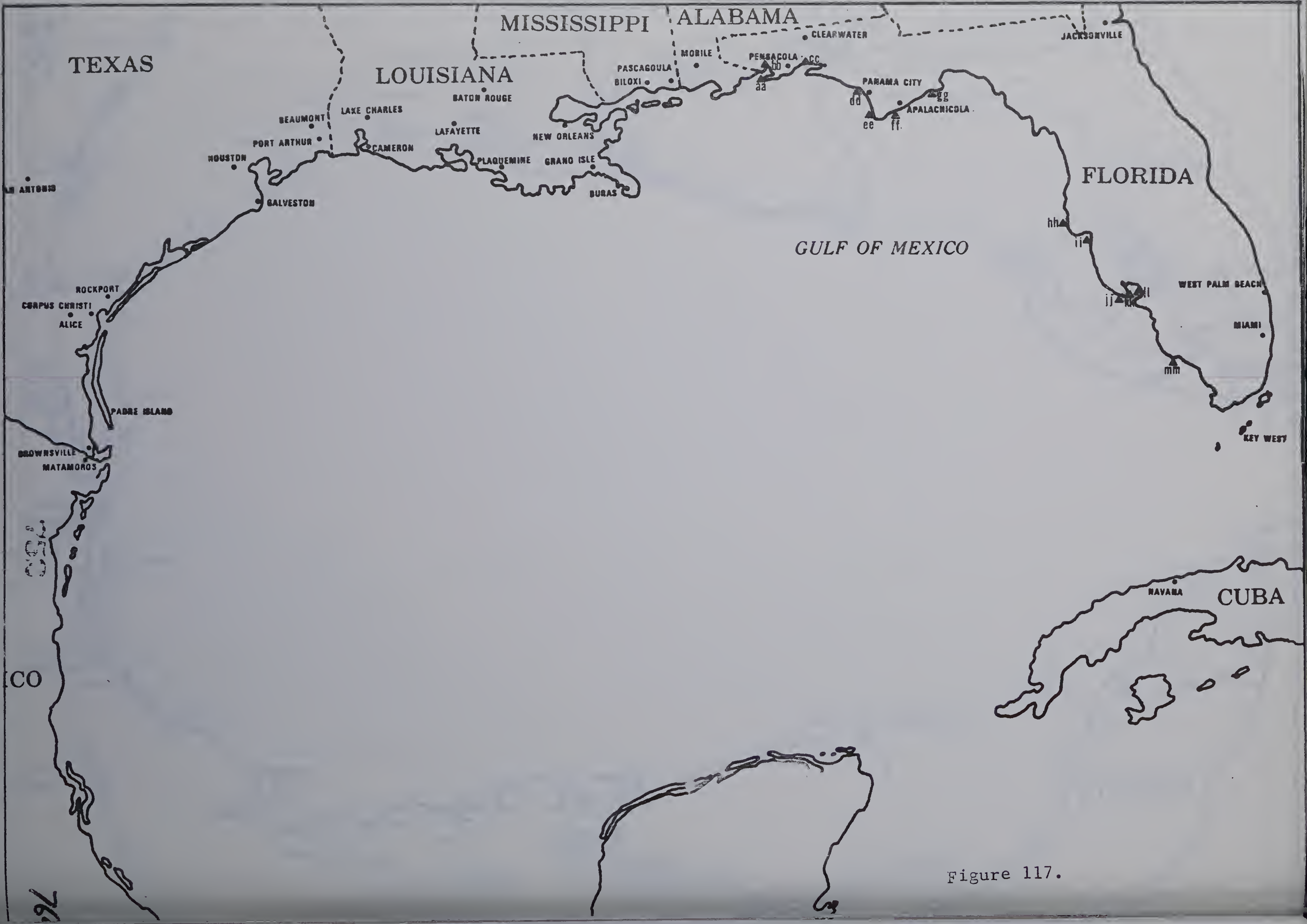


Figure 116.

▲ STATE WILDLIFE MANAGEMENT AREAS AND REFUGES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CLEARWATER
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TEXAS
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BILOXI
PANAMA CITY
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LAKE CHARLES
BEAUMONT
LAFAYETTE
NEW ORLEANS
PORT ARTHUR
CAMERON
HOUSTON
PLAQUEMINE
GRAND ISLE
FLORIDA
AN ANTONIO
BURAS
GALVESTON
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ROCKPORT
CORPUS CHRISTI
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WEST PALM BEACH
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PADRE ISLAND
BROWNSVILLE
MATAMOROS
KEY WEST
HAVANA
CUBA
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Figure 117.

(3) Ports and Shipping

The economic structure of the Gulf coast is highly dependent on its transportation systems in general, and on water transportation in particular. The area has developed an intricate navigation infrastructure which handles both deep-draft ocean shipping and inland waterway traffic. Major ports on the Gulf Coast include: Texas-Brownsville, Corpus Christi, Port O'Connor, Freeport, Texas City, Houston, Galveston, Beaumont, Orange, Port Arthur; Louisiana-Lake Charles, Baton Rouge, New Orleans; Mississippi-Pascagoula; Alabama-Mobile; Florida-Pensacola, Panama City, Port St. Joe, Tampa. The ports of New Orleans and Houston are respectively the second and third largest in the United States in terms of tonnage handled. Texas rivals New York as the leading seafaring state, and Louisiana is third. Crude petroleum and petroleum products are the largest commodity handled Gulf wide, with agricultural produce second.

Numerous navigable waterways provide links between the coastal ports and the interior ports. Much of the inland waterway traffic is barge. The major coastwise inland waterway is the Gulf Intracoastal Waterway, which extends from Brownsville, Texas to near Apalachee Bay, Florida. It covers 1,113 miles and the most heavily travelled portion is between the Mississippi River (at New Orleans), and the Sabine River on the Louisiana-Texas border. Immediately east of New Orleans the tonnage drops sharply and southwest of Sabine tonnage drops progressively down the Texas coast. The Canal is especially important to the petroleum and chemical industries of Texas and Louisiana, providing low cost movement of products to the interior of the nation. The most important interior waterway is the Mississippi River, which opens up the extensive market areas along the Mississippi-Ohio River systems to products produced along the Gulf Coast. Louisiana in general, and New Orleans in particular, are focal points for inland waterway traffic, as they contain the confluence of these two major waterways.

Because of the vast petroleum resources contained and/or processed within the west and central Gulf Coast area, portions of the Texas and Louisiana coast have developed some of the greatest concentrations of pipelines in the world. This infrastructure includes gas as well as crude oil and products lines, and ties in offshore and onshore production. These lines transmit enormous quantities of gas and oil to processing and consuming centers nationwide. As production and processing activities are less in the eastern Gulf, the density of lines drops sharply. There are virtually no crude oil product lines in Florida, and only one major natural gas line in its coastal area.

The coastal zones of all states are served by a network of railroads, principally freight oriented, that interconnect the entire region and tie it to inland areas and the rest of the nation. Railroad trackage is greatest in the western Gulf because the commodity movement demands of the region are higher. Railroads support all major ports by transporting goods to and from the coastal areas, generally such trackage is sufficient as volumes moved are generally less than existing capacity. Because of the physical constraints to construction of railroads along the immediate coast, the main lines or corridors in a coast-wise direction are generally somewhat inland. Spur lines serve the population and industrial centers and ports closer to the coast.

Highways criss-cross the coastal zone to serve the people and commodity movement requirements of the area, with trucking providing a large segment of the goods movement capability. The main movement corridors are near the populations and industrial centers of Houston-Galveston, New Orleans-Baton Rouge, Mobile, and Tampa-St. Petersburg. Because of coastline irregularities, coastwise highways are generally somewhat inland, with major arteries extending to population - industrial centers on the coast.

Air service, both passenger and cargo exists to all major cities in the coastal zone.

(4) Commercial Fisheries

In 1973, the United States commercial harvest of finfish, shellfish, and other aquatic life amounted to 4.7 billion pounds, worth a record $907.4 million to the fishermen. Landings in the Gulf of Mexico accounted for 32.7% or 1.5 billion pounds and 29.6% or $268 million of the U. S. catch (Table 53). Shrimp was the leading fishery followed by menhaden.

Overall production for the Gulf was lower in 1973 than the previous year. The primary factor causing the decrease was the tremendous influx of freshwater into the Gulf and bays and sounds of the upper Gulf. A secondary factor was low water temperatures thru late spring.

Shrimp, which accounted for 72.7 per cent of all fishery products landed on the Gulf for 1973, were the most severely affected. Statistics released by the National Marine Fisheries Service showed that shrimp landings were off 30% in Louisiana, 55% in Mississippi, 15% in Texas, and 31% in Alabama for 1973. Landings in Florida were up 12% due to the increase of the catch of pink shrimp on the Dry Tortugas grounds.

In 1973, menhaden landed on the Gulf was off about 5% and oysters were also down. The industrial (petfood, etc.) fisheries and finfish for human consumption was above normal. Crab catches were also above normal for the Gulf in 1973.

The shrimp industry was the most valuable fishery in the U. S. and the Gulf. Shrimp landed on the Gulf amounted to 203 million pounds and

Table 53.
Gulf Commercial Landings
by States 1/
1972 - 1973

	1972				1973			
	Thousand Pounds	%	Thousand Dollars	%	Thousand Pounds	%	Thousand Dollars	%
Gulf	1,584,799		223,419		1,547,471		268,146	
Alabama	39,564	2.5	18,326	8.2	39,749	2.6	18,080	6.8
Florida(Gulf)	97,422	6.1	36,269	16.2	99,200	6.4	43,462	16.2
Louisiana	1,070,597	67.6	71,916	32.2	1,035,959	66.9	98,446	36.7
Mississippi	260,216	16.4	11,897	5.3	271,594	17.6	16,887	6.3
Texas	117,000	7.4	85,011	38.1	100,969	6.5	91,271	34.0

Ranking
in
U.S. (1973)

	Catch	Value
Louisiana	1	3
Mississippi	5	15
Texas	12	4
Florida (Gulf)	13	9
Alabama	17	14

Table 54.
Preliminary Landings by Species
For Gulf of Mexico - 1973

	Thousand Pounds	%	Thousand Dollars	%
1. Shrimp	203,000	13.1	195,000	72.7
2. Menhaden	1,100,000	69.3	44,000	16.6
3. Oysters	14,910	1.0	9,646	3.6
4. Crabs	42,926	2.8	5,264	2.0
5. Red Snapper	8,171	.5	5,020	1.9
6. Other	____	13.3	___	3.2

1/ Landings in interior waters estimated, except Florida; all landings for 1973 are preliminary.
Sources: Dept. of Commerce, National Marine Fisheries Service, Washington, D. C. and O. B. Lynam, Texas Parks and Wildlife Service, Seabrook, Texas

Other marine species taken commercially in the Gulf of Mexico include:

FINFISH

1. Amberjack
2. Angelfish
3. Ballyhoo (halfbeak)
4. Bluefish
5. Blue runner or hardtail
6. Cabio (ling)
7. Crevalle (jacks)
8. Croaker
9. Dolphin
10. Drum:
    black
    sea
11. Flounders
12. Groupers
13. Grunts
14. Hogfish
15. Jewfish
16. King Mackeral
17. King whiting
    (kingfish)
18. Mullet:
    black
    silver
19. Permit
20. Pigfish
21. Pompano
22. Sand perch (mojarro)
23. Sea bass
24. Sea catfish (gafftop)
25. Sea trout:
    gray
    spotted
    white
26. Sharks
27. Sheepshead, saltwater
28. Snapper:
    lane
    mangrove
    mutton
    vermilion
    white
    yellow tail
29. Spanish mackeral
30. Spot
31. Tenpounder (ladyfish)
32. Tilefish
33. Triggerfish
34. Tripletail (blackfish)
35. Warsaw grouper
36. Unclassified:
    for food
    for bait, reduction
    and animal food
37. Red (redfish)

SHELLFISH

1. Spiny lobsters
2. Squid
3. Stone crabs
4. Spanish lobster
5. Conchs
6. Sunray venus clams

OTHER

1. Terrapin
2. Turtles, sea
3. Sponges
    grass
    sheepswool
    yellow

Source: U. S. Dept. of Commerce, National Marine Fisheries Service

195 million dollars. These figures represented 13.1% of the catch and 72.7% of the total value. Of these figures, bait shrimp accounted for approximately 40% of the poundage caught and 10% of the dollar value.

Based on 1972 statistics, brown shrimp (*Penaeus aztecus*) comprised 64% of the catch, white shrimp (*P. setifeus*) 29%, and pink shrimp (*P. duorarum*) 7% (Figure 55). Minor catches of sea bob (*Xiphopeneus kroyeri*) and the deepwater royal reds (*Hymenpenaeus robustus*) were also reported, but accounted for less than 1/2 per cent of the catch. The areas of greatest harvest were grid zones 19, 13, and 14 (Table 55). See Figure 118 for location of grid zones.

Menhaden represented the largest catch category (1.1 billion pounds or 69.3% of the Gulf catch). The value of the catch was $44 million (16.6%) for 1973. Louisiana and Mississippi were the leading Gulf States in Menhaden landings with Louisiana first. Together with shrimp, these two categories represented 82.4% of the catch and 89.3% of the total value of the Gulf fisheries (Table 54).

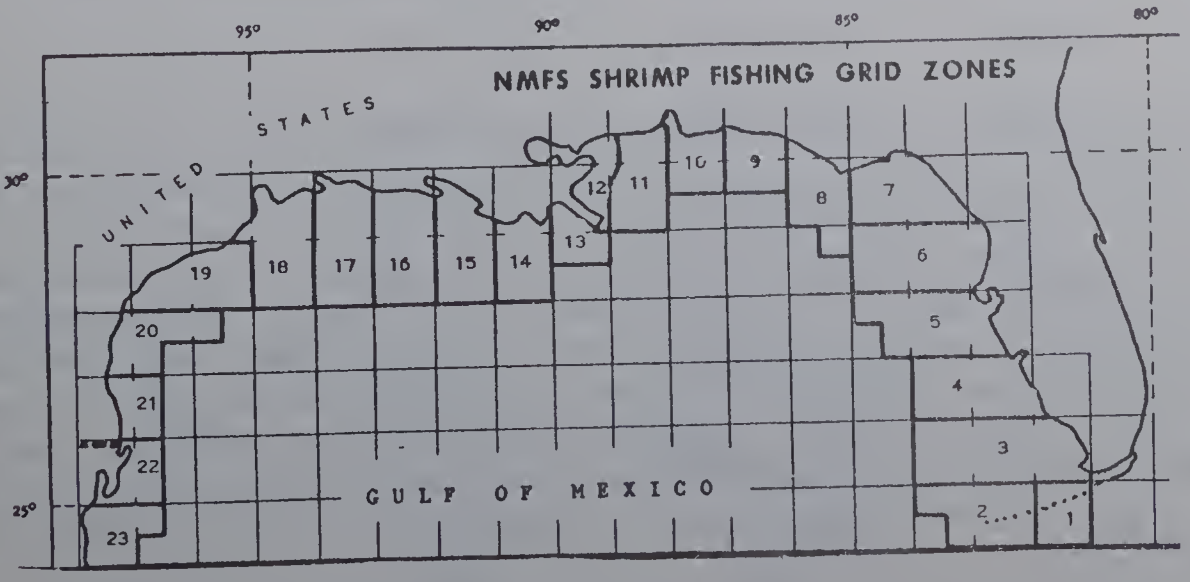

Figure 118.

Table 55.

Shrimp Catch* by Grid Zone
1972

Grid	Pink	Brown	White	% of total
001	27,854	0	0	<1
002	6,471,797	1,730	0	5
003	768,453	0	0	1
004	1,114,180	0	1,548	1
005	402,138	0	0	<1
006	182,347	0	0	<1
007	918,800	61,846	108,931	1
008	807,960	213,982	335,396	1
009	17,835	61,534	0	<1
010	62,184	457,529	37,379	<1
011	173,942	9,080,691	1,169,948	8
012	11,459	3,351,777	773,182	3
013	3,341	11,116,819	3,909,982	12
014	580	9,972,039	4,642,401	11
015	25	3,194,637	7,971,609	9
016	194	2,174,831	4,071,101	5
017	230	4,545,204	4,311,899	7
018	0	5,133,120	4,158,494	7
019	5,063	17,671,641	4,697,489	17
020	25	10,168,246	748,400	8
021	0	4,742,285	135,312	4
	10,968,407 7%	81,947,911 64%	37,073,071 29%	

Total lbs. = 129,989,389

* Heads - off weight in lbs.

(5) Oil and Gas Resources

The following estimates of oil and gas resources are provided by U.S. Geological Survey. USGS emphasizes that the estimates are speculative; only the maximum credible expectations are shown.

TABLE 56. Measured and inferred Reserves, 0-200 meter water depth.

(12-31-72)

(Oil in billions of barrels and includes natural gas liquids)

(Gas in trillion of cubic feet)

	Measured Reserves		Inferred Reserves	
Area	Oil	Gas	Oil	Gas
Eastern Gulf	0	0	0	0
Central Gulf	4	43	2-3.5	21-41
Western Gulf	Neg.	1	0	1

TABLE 57. Estimates of undiscovered recoverable resources, 0-200 meters water depth. 1/

(Oil in billions of barrels and includes natural gas liquids)

(Gas in trillions of cubic feet)

1/ On March 26, 1974, the U.S. Geological Survey released estimates of the undiscovered recoverable oil and gas resources for broad areas of the OCS. Those estimates were based on statistical parameters of oil occurrences that apply only to broad geographic areas. It is entirely inappropriate to apply the same parameters to small, specific areas. The resource figures in the above table represent a general estimate, based on the above referenced table, of minimum and maximum volumes of oil and gas that might be recovered from the various OCS areas. It is statistically unsound to add the maxima and minima for an expectable range of resources for any larger area.

Area	Estimated undiscovered recoverable resources	
	Oil	Gas
Eastern Gulf	0-20	0-110
Central Gulf	0-20	0-100
Western Gulf	0-20	0-110

TABLE 58. Current (1972) oil and gas production from coastal State waters.

(Oil in billions of barrels and includes natural gas liquids)

(Gas in trillions of cubic feet)

Area	Oil and gas production (1972)	
	Oil	Gas
Eastern Gulf	0	0
Central Gulf	0.1	0.6
Western Gulf		

TABLE 59. Estimate of undiscovered recoverable resources in coastal State waters. 1/

(Oil in billions of barrels and includes natural gas liquids)

(Gas in trillions of cubic feet)

Area	Estimated undiscovered recoverable resources	
	Oil	Gas
Eastern Gulf	0-2	0-10
Central Gulf	0-2	0-10
Western Gulf	0-2	0-10

TABLE 60. Measured and inferred reserves, coastal State lands (12-31-72).

(Oil in billions of barrels and includes natural gas liquids)

(Gas in trillions of cubic feet)

Area	Measured Reserves		Inferred Reserves	
	Oil	Gas	Oil	Gas
Eastern Gulf	0	0	0	0
Central Gulf	0.5	6.5	0-.5	3-5
Western Gulf				

1/ Ibid.

(6) Military Uses

There is extensive military use of the U.S. coastal shore areas. It is difficult to generalize about the varied military uses of these areas. Prior to granting leases in any coastal area the Department of Defense will designate the zones within the nominated area which are used for security, defense warning, or other military purposes. Negotiations with DOD and DOI will then follow.

(7) Historical and Projected Economic Growth Gulf of Mexico Region

The economic activity that has occurred in the areas bordering the Gulf of Mexico has been a significant part of the total economic activity of the nation.

The states bordering the Gulf of Mexico include Texas, Louisiana, Mississippi, Alabama, and Florida. The coastal area of Texas will be considered to be the Western Gulf of Mexico region, the coastal portion of Louisiana will be considered to be the Central Gulf of Mexico region, and the coastal portions of Mississippi, Alabama, and the western part of the coastal region of Florida will be considered to be the Eastern Gulf of Mexico.

During September, 1972, the U. S. Water Resources Council published the 1972 OBERS Projections of economic activity in the United States. These projections consist of historical and projected data incorporating population, employment, and income and earnings information classified by state and by region. The 1972 projections utilized population projections published by the Census Bureau, and were based on the Series C fertility rates. Recently, the projections of economic activity in the various OBERS Economic Areas based on the Series E fertility rates have become available. Projections based on Series E forecast a lower level of population in future years.

The coastal portion of Texas, comprising the Western Gulf of Mexico Region, is included within BEA Economic Areas 140, 141, 142, 143 and 144.

The coastal portion of Louisiana and part of Mississippi, comprising the Central Gulf of Mexico Region, is included with BEA Economic Areas 138 and 139.

The coastal portions of Alabama, a portion of the Mississippi Coastal area, and the major portion of the western coastal area of Florida are included in BEA Economic Areas 037, 038, 039, and 137. This area is referred to as the Eastern Gulf of Mexico Region.

A comparison of the population, employment, and personal income of the inhabitants of these regions with the total U. S. population, employment and personal income is shown below:

Table 61. Population, Employment, and Income Regions and U. S., 1970

		Gulf of Mexico		
	Total U.S.	Western	Central	Eastern
Total Population	203,857,864	4,883,064	2,900,230	3,267,717
% of U. S.	- - -	2.4%	1.4%	1.6%
Total Employment	79,306,527	1,816,283	963,028	1,138,419
% of U. S.	- - -	2.3%	1.2%	1.4%
Total Personal Income	$708,583,931	$15,059,700	$7,973,192	$9,150,233
% of U. S.	- - -	2.1%	1.1%	1.3%

Note = Total Personal Income in thousands of 1967 dollars.

Perhaps the most significant relationship revealed in the table is that, in all three regions, employment and personal income is a smaller percentage of national employment and personal income than is the percentage of population of the total U. S. population.

A significant trend that has been present during the last decade in the economic climate of the states bordering the Gulf of Mexico has been the decline in farm employment and the increase in employment in manufacturing and such non manufacturing categories as mining, construction, transportation, and services. Total cash farm income has increased during the last decade, however, and the indexes of production provided in the OBERS reports project increases in the production of crops and livestock in the future.

Employment in the various manufacturing industries has increased during the past decade, and the value added by manufacture has increased in the five state region. The OBERS indexes of production for selected industries indicate that increases in output for the various manufacturing activities are projected for the future.

Within the non manufacturing category, increases in output are projected for crude petroleum and natural gas in each of the states bordering the Gulf of Mexico.

On the following pages, some of the significant developments in each of the states during the past decade are presented. The data were drawn from publications prepared by the Research Department of the Federal Reserve Bank of Atlanta, and from statistical tables contained in the Texas Almanac and State Industrial Guide, published in 1973 by the A. H. Belo Corporation.

The projections of future economic activity in the states bordering the Gulf of Mexico were obtained from the 1972 OBERS Projections (Vol. 5), prepared by the U. S. Department of Commerce and the U. S. Department of Agriculture for the U. S. Water Resources Council.

The following table, based on data obtained from the 1972-E OBERS Projections, presents the earnings data for selected industries in the Gulf of Mexico coastal regions during 1970.

Table 62. Total Earnings by Selected Industries, 1970
(In thousands of 1967 dollars)

		Gulf of Mexico		
Industry	Total U.S.	Western	Central	Eastern
Agriculture, Forest & Fisheries	19,640,721	408,029	226,622	287,381
Mining	5,647,503	448,490	407,977	39,610
Manufacturing	156,291,199	2,415,108	1,137,201	1,216,005
Services	85,077,671	1,792,200	884,246	1,024,935
Government	99,310,475	2,350,310	1,073,445	1,518,090

The BEA economic regions included within the classification of Western Gulf of Mexico, Central Gulf of Mexico, and Eastern Gulf of Mexico form only a portion of the various states bordering the Gulf of Mexico. The following economic summaries incorporate information concerning the economic climate on a statewide basis and therefore are more general than economic data pertaining only to the coastal regions. However, some economic factors have effects over larger geographic areas than the region, or the coastal zone.

Alabama

During the period 1962 to 1972, total personal income in Alabama increased from $5,317 millions of dollars to $12,004 millions of dollars. Per capita personal income increased from $1,600 in 1962 to $3,420 in 1972.

The total cash farm income in Alabama increased from $573 millions of dollars in 1962 to $988 millions of dollars in 1972. The cash farm receipts from livestock and products increased from $332 millions of dollars in 1962 to $616 millions of dollars in 1972. During the same period of time, the cash farm receipts from crops increased from $218 to $303 millions of dollars. Farm employment however, decreased from 138,000 in 1962 to 82,000 in 1972, and the total farm population decreased from 402,855 in 1960 to 222,196 in 1970. An exception to the declining farm population occurred in the southwestern area of the state, where the farm population in the Gulf Truck area increased from 12,442 in 1960 to 19,432 in 1970.

Alabama's coal production increased from 12,880 thousand net tons in 1962 to 17,945 net tons in 1971. Petroleum production during 1972 in Alabama amounted to 9,889 thousands of barrels, compared to 7,473 thousands of barrels in 1962. During the period 1967 through 1971, the annual petroleum production in Alabama ranged from 7.3 to 7.8 millions of barrels.

Construction employment increased from approximately 41 thousand in 1962 to 57 thousand in 1972, and the value of construction contracts awarded during 1972 amounted to $1,355 millions of dollars, compared to $721 millions of dollars in 1962.

Manufacturing employment in Alabama increased from 240,000 in 1962 to 328,000 in 1972. During 1970, approximately 29 per cent of the civilian employment in Alabama was in the manufacturing category. Approximately half of the employment in manufacturing was in the production of durable goods, particularly in the metal industries. The largest percentage of employment in the manufacturing of nondurable goods was in the category of textiles and textile products. The value added by manufacture increased from $2,075 to $4,531 millions of dollars between the years 1962 and 1971.

During 1967, approximately 29,000 persons were employed in retail trade establishments in a multi county area in the southwestern portion of the state. An additional 8 thousand were employed in wholesale trade establishments.

Florida

During the period 1962 to 1972, total personal income in Florida increased from $11,039 to $31,779 millions of dollars. Per capita personal income increased from $2,022 in 1962 to $4,378 in 1972.

The total cash farm income in Florida increased from $899 millions of dollars in 1962 to $1,681 millions of dollars in 1972. The cash farm receipts from livestock and products increased from $213 millions of dollars in 1962 to $464 millions of dollars in 1972. The cash farm receipts from crops increased from $676 millions of dollars in 1962 to $1199 millions of dollars in 1972. Farm employment, however, decreased from 122 thousands in 1962 to 114 thousands in 1972. The farm population, however, increased from approximately 105 thousand in 1960 to approximately 150 thousand in 1970.

Petroleum production in Florida increased from 419 thousands of barrels in 1962 to 16,897 thousands of barrels in 1972, due in large part of oil discoveries in the northwestern part of the state.

Construction employment increased from 110 thousand in 1962 to approximately 204 thousand in 1972, and the value of construction contracts awarded increased from $1,642 millions of dollars in 1962 to $6,522 in 1972.

Manufacturing employment in Florida increased from 222 thousands to 335 thousands of workers during the period 1962 to 1972.

During 1970, approximately 54 per cent of the employment in manufacturing was in the category of durable goods. Approximately 11 per cent of the manufacturing employment occurred in the metal industries, and an additional 11 per cent of the employment occurred in the electrical machinery industry. An important industry in the nondurable goods manufacturing category is the production of food and kindred products.

During 1967, total retail sales in Florida amounted to $10,280 millions of dollars. During 1970, approximately 4.5 per cent of the total civilian employment in Florida was in the category of wholesale trade, and approximately 19 per cent of the civilian employment was in the category of retail trade.

Louisiana

During the period 1962 to 1972, total personal income in Louisiana increased from $5,901 to $13,179 millions of dollars. Per capita personal income increased from $1,764 during 1962 to $3,543 in 1972.

The total cash farm income in Louisiana increased from $448 millions of dollars in 1962 to $882 millions of dollars in 1972. Cash farm receipts from livestock and products increased from $164 millions of dollars in 1962 to $324 millions of dollars in 1972. Cash farm receipts from crops increased from $264 millions of dollars in 1962 to $507 millions of dollars in 1972. Farm employment, however, declined from 144 thousand in 1962 to 73 thousand in 1972, and farm population decreased from 233 thousand in 1960 to 171 thousand in 1970.

Petroleum production in Louisiana increased from approximately 477 million barrels in 1962 to approximately 896 million barrels in 1972, although the production during 1972 was below the levels attained during 1970 and 1971.

Construction employment increased from approximately 53 thousand in 1962 to 85 thousand in 1972, and the value of construction contracts awarded increased from $659 millions of dollars in 1962 to $2,036 millions of dollars in 1972.

Manufacturing employment in Louisiana increased from 139 thousand in 1962 to 179 thousand in 1972. During 1970, approximately 40 per cent of the manufacturing employment in southern Louisiana was in the durable goods industries, and approximately 60 per cent of the employment in manufacturing was in the nondurable goods category.

Approximately 10 per cent of the manufacturing employment in southern Louisiana during 1970 occurred in the metal industries, and almost 18 per cent of the total manufacturing employment was in the category of chemicals and allied products.

Employment in retail trade in the city of New Orleans, and including a portion of the adjacent area of the State of Mississippi, amounted to approximately 76 thousand persons during 1967, and an additional 31 thousand were employed in wholesale trade in the same area.

Mississippi

During the period 1962 to 1972, total personal income in Mississippi increased from $2,978 to $7,099 millions of dollars. Per capita personal income increased from $1,328 in 1962 to $3,137 in 1972.

The total cash farm income in Mississippi increased from $704 millions of dollars in 1962 to $1,210 millions of dollars in 1972. Cash farm receipts from livestock and products increased from $290 millions of dollars in 1962 to $550 millions of dollars in 1972. Cash farm receipts from crops increased from $396 millions of dollars to $535 millions of dollars during the same time span. Farm employment decreased from 225 thousand in 1962 to 113 thousand in 1972, and total farm population decreased from approximately 543 thousand to 261 thousand during the period 1960 to 1970. In the Gulf truck area, however, farm population increased from 3,359 to 5,869 during this period.

Petroleum production in Mississippi increased from 55,713 thousand barrels in 1962 to 61,075 thousands of barrels in 1972, but production during the year 1969, 1970 and 1971 were at higher levels than the rate attained during 1972.

Construction employment increased from approximately 23 thousand in 1962 to 35 thousand in 1972, and the value of construction contracts awarded during 1972 amounted to 885 millions of dollars, compared to $267 millions of dollars in 1962.

Manufacturing employment in Mississippi increased from 128 thousand in 1962 to 205 thousand in 1972. During 1970, approximately 55 per cent of the manufacturing employment in the southern half of the state occurred in the manufacture of durable goods. The balance of employment within the category of manufacturing was in the production of nondurable goods. The largest percentage of persons employed in the nondurable goods category were engaged in the production of textiles and fabricated textile products.

For the entire state output, the value added by manufacture increased from $849 to $2,237 millions of dollars between the years 1962 and 1971.

Texas

During the period 1962 to 1972, total personal income in Texas increased from $20,518 to $47,121 millions of dollars. Per capita personal income increased from $2,019 during 1962 to $4,045 in 1972.

The total cash farm receipts in Texas increased from $2,575 millions of dollars in 1962 to $3,772 millions of dollars in 1971. Cash farm receipts from livestock and products increased from $1,075 millions of dollars in 1962 to $2,122 millions of dollars in 1971. Cash farm receipts from crops decreased from $1,352 millions of dollars in 1962 to $1,132 millions of dollars in 1972. Agricultural employment declined from 299 thousand in 1962 to 281 thousand in 1972, and total farm workers decreased from 415 thousand in 1962 to 275 thousand in 1972. Hired workers, included in the figures for total farm workers, decreased from 172 thousand in 1962 to 88 thousand in 1972.

Crude oil production in Texas increased from approximately 943 million barrels in 1962 to approximately 1,301 million barrels in 1972.

Contract construction employment amounted to approximately 252 thousand in 1972, and the value of construction contracts awarded amounted to $1,651 millions of dollars in 1972, second only to the record 1971 amount of $1,751 millions of dollars.

Manufacturing employment in Texas increased from 500 thousand in 1962 to 741 thousand in 1972. During 1972, approximately 398 thousand workers were employed in the manufacture of durable goods, and approximately 343 thousand were employed in manufacturing nondurable goods.

Employment in wholesale and retail trade amounted to approximately 951 thousand persons in 1972. Employment in water transportation amounted to approximately 21 thousand, and employment in pipeline transportation amounted to approximately 5 thousand during 1972.

In considering the coastal portions of the states bordering the Gulf of Mexico, during the period 1950 to 1970, the percentage increase in population and employment in all three regions was greater than the percentage increase in national population and employment. During the period 1970 to 1990, population and employment in the Eastern and Western Gulf of Mexico Regions is expected to increase at greater percentage rates than the national percentage rates.

The following table contains the population and employment data, both historical and projected, for the BEA Areas included within the various regions adjacent to the Gulf of Mexico.

Table 63. Regional Population and Employment

Region	1950	1970	% Change 1950-1970	1990	% Change 1970-19
Eastern Gulf BEA Areas 037,038,039,137					
Population	1,698,259	3,267,717	92.4%	4,732,900	44.8%
Employment	600,384	1,138,419	89.6%	1,704,200	49.7%
Central Gulf BEA Areas 138,139					
Population	2,070,014	2,900,230	40.1%	3,142,900	8.4%
Employment	692,826	963,028	39.0%	1,186,500	23.2%
Western Gulf BEA Areas 140,141,142,143,144					
Population	3,140,093	4,883,064	55.5%	6,078,000	24.5%
Employment	1,133,386	1,816,283	60.3%	2,535,700	39.6%
United States					
Population	151,236,648	203,857,864	34.8%	246,039,000	20.7%
Employment	57,474,912	79,306,527	38.0%	106,388,000	34.1%

Source = OBERS 1972 E Projections

The following pages contain some of the pertinent demographic and economic data developed for the BEA Economic Areas included within the regions adjacent to the Gulf of Mexico.

Table 64. Population, Employment, and Per Capita Income, Historical and Projected 1950-2000 (1972-E, OBERS Projections, Bureau of Economic Analysis)

BEA	Economic Area	1950	1970	Percent Change 1950-1970	1980	1990	2000
037	St. Petersburg, Fla.						
	Population	706,870	1,812,456	156.4%	2,440,100	2,968,100	3,409,900
	Per Capita Income	1,750	2,997	71.3%	4,200	5,500	7,300
	Total Employment	256,872	615,382	139.6%	851,300	997,500	1,141,400
038	Tallahassee, Fla.						
	Population	259,490	345,749	33.2%	414,800	487,000	542,500
	Per Capita Income	1,124	2,513	123.6%	3,500	4,700	6,400
	Total Employment	87,909	127,558	45.1%	168,000	199,400	231,100
039	Pensacola, Fla.						
	Population	207,346	384,529	85.5%	394,700	437,800	465,200
	Per Capita Income	1,527	2,718	78.0%	3,700	4,800	6,500
	Total Employment	70,961	143,304	101.9%	161,000	178,800	196,700
137	Mobile, Ala.						
	Population	524,553	724,983	38.2%	768,400	840,000	870,900
	Per Capita Income	1,435	2,488	73.4%	3,500	4,600	6,300
	Total Employment	184,642	252,175	36.6%	296,900	328,500	355,000
138	New Orleans, La.						
	Population	1,535,505	2,149,598	40.0%	2,284,200	2,440,000	2,528,600
	Per Capita Income	1,641	2,849	73.6%	3,900	5,200	7,000
	Total Employment	530,342	717,945	35.4%	854,000	928,900	1,012,500
139	Lake Charles, La.						
	Population	534,509	750,632	40.4%	695,800	702,900	685,400
	Per Capita Income	1,256	2,463	96.1%	3,400	4,500	6,200
	Total Employment	162,484	245,08[illegible]	50.8%	251,400	257,600	263,800

Per Capita Income is expressed in 1967 dollars.

Table 64, cont. Population, Employment, and Per Capita Income, Historical and Projected 1950-2000

(1972-E, OBERS Projections, Bureau of Economic Analysis)

BEA	Economic Area	1950	1970	Percent Change 1950-1970	1980	1990	2000
140	Beaumont-Port Arthur-Orange, Texas						
	Population	299,857	396,723	32.3%	432,800	484,900	520,100
	Per Capita Income	1,820	3,105	70.6%	4,200	5,500	7,400
	Total Employment	106,986	140,677	31.5%	168,800	192,300	215,800
141	Houston, Texas						
	Population	1,257,035	2,374,842	88.9%	2,832,400	3,362,700	3,780,400
	Per Capita Income	2,308	3,519	52.5%	4,700	6,100	8,000
	Total Employment	485,199	945,995	95.0%	1,244,700	1,474,400	1,701,900
142	San Antonio, Texas						
	Population	853,013	1,235,581	44.8%	1,245,900	1,352,000	1,417,200
	Per Capita Income	1,674	2,770	65.5%	3,800	5,000	6,800
	Total Employment	309,559	451,412	45.8%	503,500	550,300	598,300
143	Corpus Christi, Texas						
	Population	407,011	518,920	27.5%	515,000	534,600	544,000
	Per Capita Income	1,525	2,651	73.8%	3,700	4,800	6,600
	Total Employment	132,095	176,319	33.5%	195,100	204,300	217,400
144	McAllen-Pharr-Edinburg, Texas						
	Population	323,177	356,998	10.5%	346,000	343,800	336,300
	Per Capita Income	1,111	1,884	69.6%	2,800	3,700	5,200
	Total Employment	99,547	101,880	2.3%	113,800	114,400	118,100

Per Capita Income is expressed in 1967 dollars.

d. Existing Environmental Quality Problems in the Coastal Zone

(1) Water Quality

Florida [1/] - Domestic pollution is greatest in the Tampa Bay system and industrial pollution is greatest in the northern estuaries. In a 1971 study, 402 sources of pollution were identified along the Florida Gulf Coast. In the study it was estimated that polluted areas make up 31% of the area of all west coast estuaries. If Florida Bay is excluded, then the polluted area amounts to 43% of the total estuarine area. Ten of the estuarine areas strongly affected by pollution are: Caloosahatchee River, Sarasota Bay system, Hillsborough Bay, Old Tampa Bay, Boca Ciega Bay, Fenholloway River, St. Joseph Bay, St. Andrew Bay, Escambia Bay Pensacola Bay, and Perdido Bay.

Besides bacterial levels, very few studies on other pollutants have been done for Florida's Gulf coast. DDT effects on brown pelican eggs have been investigated; apparently the problem is most critical in southeastern Florida but also has been noted in Pinellas County. A PCB has been detected in the biota, water, and sediments of Escambia Bay. In 1970 Tampa Bay was polluted by 5,000-10,000 gallons of Bunker C fuel oil, causing considerable damage to seabirds and beaches, but no long term results of this spill have been reported. Minor oil spills have occurred in Pensacola Bay and St. Joseph Harbor. Perdido Bay receives discharge from a paper mill located on the Florida side along with inadequately

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[1/] Sources of Information: McNulty, Lindal, and Sykes (1972), Stursa (1973), Taylor (1970).

treated waste discharged into Bayou Marcus. There are no significant discharges, industrial or municipal, into Perdido Bay from Alabama sources.

Alabama [1] - Water quality degradation in the Mobile Bay area is primarily the result of municipal and industrial discharges from sources in Mobile. Sewage outfalls from commercial development along the Alabama Gulf coast are minor and result in only localized water quality degradation.

There were 23 sources of domestic pollution in Mississippi Sound, Mobile Bay and the Mobile River Delta in a July, 1970 inventory. The effluent from 19 of these sources averaged 25.592 million gallons per day, and amount of treatment ranged from untreated to a high degree of secondary treatment. Unknown amounts of domestic sewage also enter the waters from ships, septic tanks, seafood processing plants and other sources. This has resulted in the permanent closing to shellfishing of about 28% of Mobile Bay. From time to time, other major oyster reefs have been closed temporarily.

Waters of Mississippi Sound, Mobile Bay and its rivers receive discharges from more than 30 industrial plants (July, 1970 inventory). The average daily effluent from 16 of these sources was over 800 million gallons with two major paper mills being the largest contributors. The effects of these industrial effluents upon the marine biota and environment have apparently not yet been assessed. However, on July 1, 1970, the Federal

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[1] Sources of Information: Crance (1971); Stursa (1973), Swingle (Unpub. Rep. of Ala. Mar. Resources Lab, 1972).

Water Quality Administration and the Alabama Public Health Department informed the public that fish from certain areas of the Mobile Delta contained levels of mercury as high as 2.5 ppm and were unsafe for human consumption. Chemical plants using mercury in the manufacture of chlorine were suspected.

The presence of certain pesticides in oysters in Mobile Bay were studied in 1969. Conclusions were that the levels of pesticides found presented no immediate health problem.

Mississippi [1] - At the present time there seem to be two main areas where the pollution problems are of major concern. The first of these two problems concerns itself with the area around Pascagoula and Escatawpa. Pollution in around this area is due primarily to heavy concentration of industry in the area.

The second area of major concern is the area in and around Biloxi and Gulfport. The pollution problems here are attributed mainly to inadequately or poorly treated human waste and to small seafood processing plants. This area is heavily populated and the waste treatment facilities cannot adequately handle the generated wasteloads.

Louisiana [2] - Water quality of the coastal waters and rivers of Louisiana generally varies as to location and season of the year. Rivers east of the Mississippi within Louisiana generally have good water quality while lakes and bays (especially Lake Pontchartrain) have poorer quality waters. Even poorer water quality is encountered in the Mississippi River. West of the Mississippi River, water quality conditions are generally considered good except in the lower Calcasieu River and parts of Calcasieu Lake and Sabine-Neches complex.

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[1] Source of Information: Barry S. Royals, Mississippi Air & Water Pollution Control Commission, Personal Communication.

[2] Source of Information: Report on Gulf Coast Deepwater Port Facilities. Appendix F Environmental Assessment Central Gulf, DOA Corps of Engineers, June 1973.

Industrial wastes emptying into the Louisiana coastal waters were estimated by Perret et. al. (1971) at approximately 1,440 million gallons per day. Greatest discharges were into the Mississippi and Calcasieu Rivers. This is due to the extensive oil-chemical processing plants located in proximity to them. Other sources of industrial discharges include sugar refineries, fish processing plants, electrical generators and meat processors. In general, water quality is not seriously deteriorated by industrial discharges along the Louisiana coast other than in the above-mentioned rivers.

Texas - Water quality degradation occurs from sewage and industrial pollutions, dredging operations, pesticides, urban and agricultural runoff, changes in hydrological regime, shipping, offshore oil operations, etc. We have been able to gather limited information and quantification of the following water quality problems.

The Corps of Engineers reviewed the water quality problems along the Texas coastline in preparation of a report on Gulf coast deepwater port facilities. (U. S. Dept. of the Army, 1973). Some of their findings are included below.

Areas of moderate to heavy pollution are shown in Figure119. Pollution levels are high in the Houston Ship Channel, along the west side of Sabine Lake and up the Neches and Sabine tidal estuaries. Pollution levels are also high in the area surrounding the city of Galveston and in a small area near a chemical plant in Lavaca Bay. Other small areas of pollution are located in tributaries of most of the bays located near oil fields, where the disposal of oil field brines takes place.

In the bays, oyster reefs reflect areas of human disturbance because they are closed to harvesting when bacterial counts or incidence of hepatitis are too high. As of September 1, 1970, the Texas Department of Health had closed virtually all reefs in Sabine Lake, almost half the reefs in Galveston Bay and over half the reefs in Lavaca Bay, representing most of the bays with significant oyster production. Acreages of closed and active reefs are indicated in Figure 119.

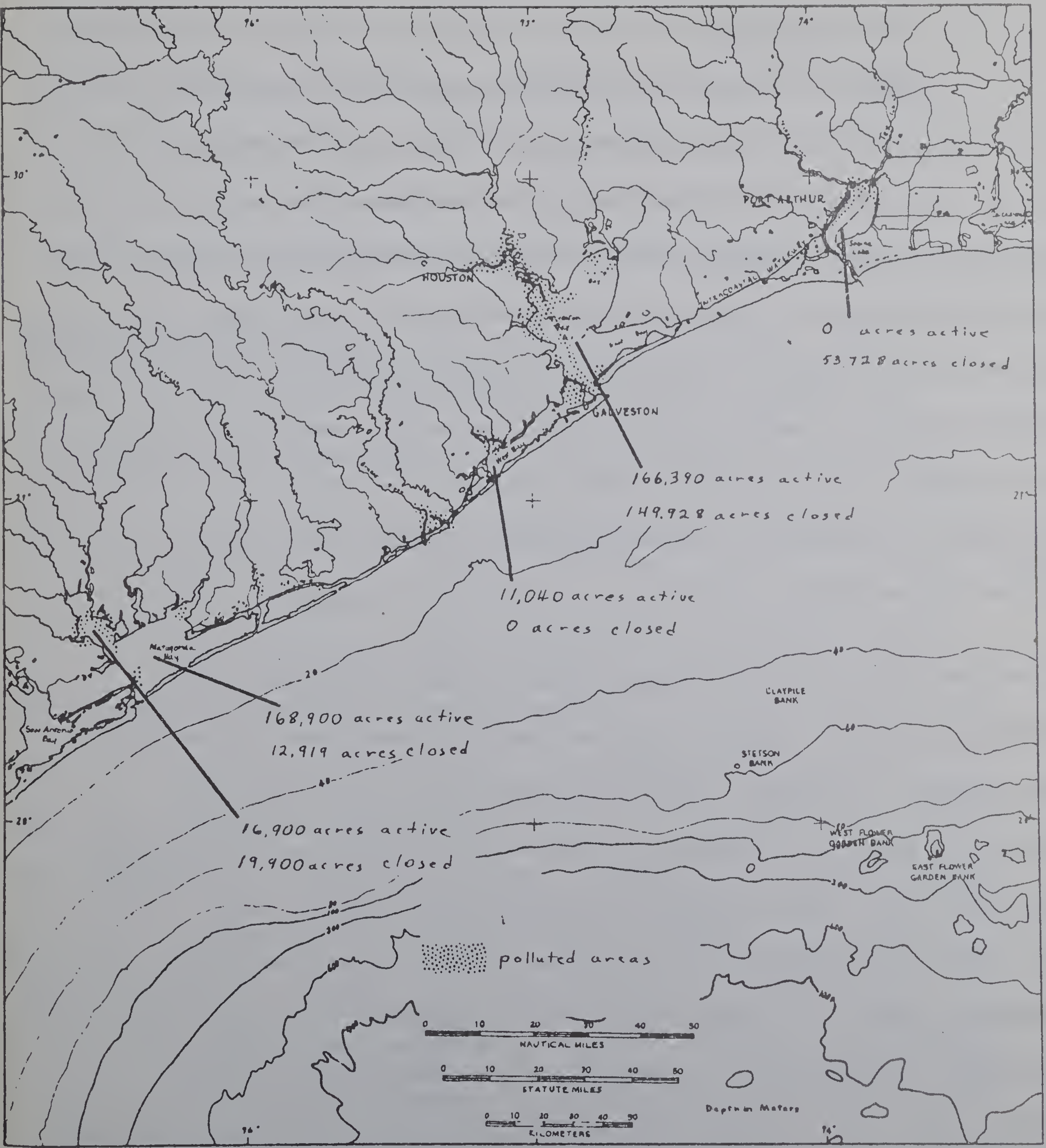

Figure 119. Areas of Moderate to Heavy Water Pollution in eastern Texas Bays and Estuaries. Areas of closed and approved (active) oyster reefs are indicated. (from U.S. Dept. of the Army, 1973).

(2) Air Quality

Texas: Because of the high concentration of population and industry, and the unique meteorology of the area, the Texas coastal region has a high potential for the occurrence of air pollution problems (Classen, 1970). The City of Houston and the high concentration of industries along the Houston Ship Channel are the two most critical air pollution locations in the zone. In addition there are numerous other locations in the coastal zone in which frequent air pollution episodes endanger the health and well-being of the public, the Beaumont-Port Arthur-Orange areas, and the Corpus Christi area being of particular concern.

The weather along the Texas Coastal Zone greatly affects the air pollution problem. The high relative humidity throughout the coastal zone presents a problem. The moisture in the air may react with some of the gaseous pollutants to form such pollutants as sulfuric and nitric acid mist which eventually settles to the ground. However, the large amount of precipitation, which is characteristic throughout most of the Texas Coastal Zone, periodically flushes the air of most contaminants. The prevailing southerly winds from the Gulf of Mexico aid in dispersing many of the high air pollution concentrations.

Louisiana: Air quality over most of Louisiana is good, being better than ambient air quality standards in all but a few areas around heavy industrial complexes. Air quality was poorest in the Baton

Rouge area near the heavy industrial complexes north of the city; suspended particulates, dustfall, sulphur dioxide and hydrocarbons exceed ambient standards. At the other station, Lafayette, Lake Charles and New Orleans, only suspended particulates consistently exceeded ambient standards during several months during 1971.

Mississippi-Alabama-Florida: Air quality in the coastal zones of these states is generally good. Notable exceptions however, are the Pascagoula area, the Mobile area, and the Tampa-St. Petersburg area.

(3) Dredging

Deterioration of the environment by dredging can result from removal of benthos and benthic habitat in the path of the dredge, turbidity of the water and burial of the benthic community where the spoil is discharged, loss of aquatic habitat by emergent spoil banks and fingerfill real estate development, alteration of natural drainage and tidal patterns by deep channels and spoil banks, erosion and salt-water intrusion in wetland areas, resuspension of toxic materials previously buried in the sediments, and perhaps others. Dredging is carried out for several purposes: landfill operations, creation and maintenance of navigation channels and canals, sand and shell dredging, and pipeline laying.

Florida: The rise in boat registrations in Gulf coast counties, up more than 1000% from 1960 to 1970, has resulted in a demand for marinas and channels to accommodate navigation and anchorage. Navigation channel dredging, begun in the 1800's, has been accelerating at a rapid pace during the twentieth century, especially since the middle 1950's. During one project, the West Coast Inland Waterway from Anclote to Fort Myers, 14 million cubic yards of material was displaced. A great deal of additional dredging and filling has been done to provide waterfront real estate development with housing sites and waterway access.

About 20% of Boca Ciega Bay has been destroyed by dredge-fill development. As a result, the normal pattern of tidal circulation has been drastically changed and an enormous volume of silt and clay has been redeposited in a natural basin north of the Pinellas County Bayway, and in the access canals between fingerfills. The dredged area and the area where material was placed were effectively lost as habitat, the dredged channel was generally too deep for regrowth of marine grasses, and spoil areas were inundated. During one study, it was estimated that the annual standing crop destroyed was 1,133 metric tons of seagrasses and 1,812 metric tons of associated marine life.

Statewide, as of 1967, of 796,000 acres of original estuarine habitat, 59,700 acres have been lost to dredging. In addition, another estimated 23,521 acres of Florida's Gulf coast have been filled by housing, industry and other development through 1967.

Alabama: The most harmful dredging project in Alabama has been the Mobile Ship Channel, which, along with its spoil banks has seriously altered circulation and sedimentation patterns within the bay. Apparently, above average rates of sediment accumulation are occurring in the southwestern portion of Mobile Bay. The effects of dredging on aquatic animals in the Mobile Bay system have been investigated on at least two occasions; the investigators observed no adverse effects in either case.

Mississippi: The lack of large urban areas on the Mississippi Gulf coast has kept the need for filling marshland to a minimum. Dredging of channels and maintenance of "Gold Coast" artificial beaches have been done at intervals, but very little has been reported with regard to biologically harmful effects of this dredging.

Pipelines have been laid across Mississippi Sound from coastal Louisiana oil fields to the Pascagoula refineries.

Louisiana: The principal dredging operations in Louisiana are for canal operations associated with the oil and gas industry, dredging to maintain navagational channels and dredging for oyster shell. It has been estimated that approximately 2.15 sq. miles of marsh are lost each year as a result of the petroleum industry activities. 1/ In addition to this dredging, constant effort must be exerted to maintain channels especially at the mouth of the Atchafalaya River

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1/ Louisiana State University, Coastal Studies Institute, "Geologic and Geomorphic Aspects of Deltaic Processes, Mississippi Delta System", Baton Rouge, La., 1970.

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and at the southwest pass of the Mississippi River. Dredging requirements have recently increased 3 to 4 times over normal in these areas. [1/]

Texas: Because of the extremely shallow character of the Texas bays, considerable dredging has taken place in order to construct navigation channels for commerce and industry located in the coastal sea ports. The Intracoastal Waterway extends the entire length of the Texas coast and is the mainstay of coastal inter- and intrastate cargo transportation. Considerable amounts of emergent spoil and land fill has been created in each of the bay systems, and especially in Galveston Bay.

[1/] Remarks by General Charles C. Noble, U. S. Army Corps of Engineers, Mississippi Academy of Science Meeting, Biloxi, Mississippi, 22 March, 1974.

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